THE DISPLACEMENT METHOD OF SINUS DIAGNOSIS AND TREATMENT

BY

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TO THE MEMORY

OF

MY FRIEND AND PRECEPTOR

GREENFIELD SLUDER

PREFACE

Twenty years ago the Displacement Method was presented to the Washington University Medical Society as the first attempt at a generalized introduction of fluids into all of the nasal sinuses at one time. On that occasion the evidence rested upon the X-ray demonstration of lipiodol in the sinuses of a cadaver and in those of the demonstrator. Slim as it was, it proved conclusively that solutions could be put into the remote cells of the anterior and posterior ethmoid groups as well as the more accessible maxillary and sphenoid cavities.

Essentially that was all there was to it. Although in the intervening years much has been written here and abroad regarding refinements and elaborations of treatment and diagnosis, no single fundamental change has been made in the technic since that time.

As the years pass new applications arise. Before the war officers in the armed forces reported significant reductions in the percentage of nasal operations in their services, and after the beginning of hostilities the method proved useful in the prevention and management of aerosinusitis and aerotitis; flight surgeons were instructed in its use.

Enough new material has come to hand since the publication of the Second Edition of this book to call for a fairly extensive revision. This will be found to consist largely of additions and amplifications, no change having been made in any technical procedures.

To quote from the preface to the first edition this work is "a practical treatise embodying primarily the theories and prac-

tices of displacement in the diagnosis and treatment of sinus disease. It includes, in some detail, the general problems of sinus diagnosis by means of fluid radiopaques. Since the successful conduct of this type of work rests not only upon the sympathetic co-operation of the laryngologist and the radiologist but also upon a complete understanding of the physical and physiological natures of this complex group of nasal cavities, these fundamental subjects have been reviewed in so far as has seemed germane to the matter in hand. In determining just how much of this collateral material to include and how much to omit, I have been guided to a great extent by the many pertinent inquiries which have come from clinicians of both groups regarding the details of the method.

"At the risk of monotony, much elementary material has been retained, partly to render the work of practical value to students, but more particularly because the behavior of fluids in sinuses, regarded from the standpoint of diagnosis, has not heretofore been of essential interest to either the laryngologist or the radiologist, and a too casual contemplation of it is likely to lead him to false deductions.

"A part of the material upon which the book is based has been recorded in a series of articles appearing, since 1925, in various laryngological and radiological journals.

"My best thanks are due my associates in the Department of Otolaryngology in Washington University (at first under the sponsorship of Dr. Greenfield Sluder and latterly of Dr. L. W. Dean) for their aid and cooperation, without which much of the most informative clinical material would not have been available for study.

"To my friend, Dr. Edwin C. Ernst, I am indebted for all the essentials and most of the details of the radiological phase

of the work. Dr. Ernst's unique facilities—mental and mechanical—have always been at my disposal; moreover, I have enjoyed the restraining influence of his caution and conservatism."

From the present revision the collection of radiographic studies of skulls in which individual sinuses had been filled with metal has been omitted and in their place are others showing oil in all the sinuses, as seen by the clinician. Accompanying them are new charts in color which it is felt will demonstrate the limits of the sinuses more clearly to the student unfamiliar with the bone shadows delineated in the various positions.

For much of the new material in the present revision I am indebted to former students and other friends lately serving in the Army and the Navy who have put the method to test under conditions which were sometimes trying, but which lent themselves especially to controlled observations in sizeable numbers, and permitted more exhaustive scientific comparisons than were available before.

ARTHUR PROETZ.

August 1946.

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CHAPTER I

INTRODUCTION

PRESENT KNOWLEDGE OF SINUSES—LIMITATIONS—ETIOLOGICAL IMPORTANCE OF RETENTION—EXISTING METHODS OF INTRASINOUS TREATMENT—CANNULIZATION—PUNCTURE—METHOD OF COFFIN—*THE DISPLACEMENT PRINCIPLE.*

Discouragingly little is known about sinuses. One becomes so accustomed to the elaboration of facts and theories which are repeated from one textbook to the next that they are seldom reduced to the few simple elements of which they really consist.

It is known, briefly, that a sinus is an air cavity communicating with the nose; that it is capable of infection and that when its ventilation and drainage are impaired trouble ensues. We recognize in a general way what are the symptoms of such infections and blockades, and too often we are mistaken. We have devised dozens of more or less ingenious ways of opening these cavities, all for one purpose—to let out infectious material; which sums up virtually the whole of sinus surgery, and cannot be considered a step ahead of the elementary surgical principle of draining an abscess anywhere in the body, as practiced by the ancients. Our treatment plays a pathetic rôle in the process of repair which Nature institutes and effectively pursues.

There are many exceedingly elementary matters about sinuses of which we know very little. To begin with, we do not know why they exist at all. We do not know exactly why

antrum and the sphenoid. It has these drawbacks: It is painful, it may be dangerous, it occasions excessive trauma when frequent irrigations are required, and above all, it establishes artificial inflammatory and vasomotor reactions, vitiating those diagnostic examinations which may depend upon the elimination time, and which should be based upon undisturbed membrane conditions.

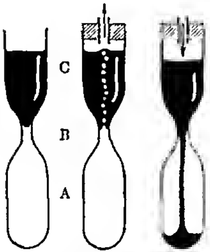

Fig. 1. The Displacement Principle. Test tube with constriction representing an ostium, between a nasal chamber, and a sinus. In the middle tube exhaustion, in the one on the right filling.

Coffin[32] has described a method of introducing vapors into the sinuses by the use of a bivalve apparatus which permits the alternate exhaustion of air and introduction of vapor through the ostia. Very small amounts of nebulizable fluids can be introduced in this way, but the method is useless for introducing the heavy, radiopaque oils.

The displacement principle, here under discussion, depends upon the elasticity of the air contained in the sinus cavities, small portions of which can be displaced by suction applied to the nostril, and replaced by droplets of any fluid in contact with the ostium at the moment when the vacuum is released.

Experiments were first conducted with test tubes in which constrictions had been made by heating. (*Fig. 1.*) In the illustration, the chamber A represents the sinus, the constriction B the ostium, and the open chamber C the nasal cavity. If fluid be poured into this latter chamber, it will not penetrate the lower chamber A, because the constriction does not permit of egress of air and ingress of fluid at the same time. If suction be applied to the mouth of the test tube, however, the volume of air contained in the chamber A will increase inversely as the pressure, and bubbles of air will escape. When the pressure is allowed to return to normal, and contraction of the air in chamber A occurs, the extruded air is replaced by fluid from chamber C. If the tube be now inverted, fluid will be retained in this chamber until some imbalance of pressure reverses the process.

This experiment was repeated on a cadaver, employing radiopaque oil as the liquid, and a negative pressure of 180 mm. of mercury. The maneuver was executed before the fluoroscope, and the oil was seen to penetrate the sinuses in like manner as it had entered the nether chamber of the test tube.

A living subject was now substituted with the same result. Since that time the method has been generally accepted in this country and abroad. It has found a place in many of the recent textbooks, and courses of graduate study. Papers appearing in the literature since the publication of the first edition of this monograph have been collected[171] and form the basis of the present revision. While the method has not always accomplished its purpose, it may be safely stated that no injury follows its proper use.

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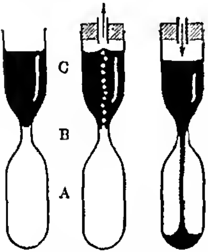

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CHAPTER II

THE PRINCIPLE AND PRACTICE OF DISPLACEMENT

MECHANISM OF THE NOSE—PRINCIPLES OF FILLING—NECESSITY OF SUCTION—THE PRACTICE OF DISPLACEMENT—RETENTION OF FLUIDS—ADVANTAGE OF DISPLACEMENT—MAXILLARY POSITION—PRONE POSITION—IMMEDIATE EFFECTS—PRECAUTIONS.

The simplest method of introducing a liquid into any cavity is, of course, to pour it in. Gravity carries the liquid to the remotest crevices of the cavity, and as it fills them it displaces the contained air.

MECHANISM OF THE NOSE. Mechanically, the nose is a rigid, air-filled chamber, with which other secondary chambers communicate through relatively small openings. (Fig. 2.) These secondary chambers have no other communications or outlets. If a liquid be poured into such a primary chamber it will overflow into the secondary chamber only provided (1) that the openings are so placed in relation to the secondary chambers that the liquid can enter by gravity, (2) that there is sufficient liquid in the primary chamber to reach the openings and (3) that the openings are of sufficient size to permit the escape of air from the secondary chambers as the liquid enters.

It is not difficult to place the nose in such a position as to bring the ostium of any given sinus uppermost. Liquids can readily be instilled into the nasal chambers. It is the third requisite which is not met by conditions encountered in the nose. The ostia are ordinarily too small to permit the exchange of air

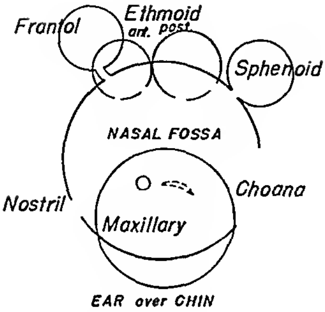


Fig. 2. Diagrammatic representation of the nose and its accessory chambers and openings, to illustrate their mechanical relations.

and liquid necessary for the unaided overflowing of the latter from the nose into the sinuses. (Fig. 3.) However, with the aid of a minimal amount of suction, applied to the nose, the air from the submerged sinus can be made to escape, a bubble at a time, and the liquid to enter in lieu of the displaced air. (Fig. 4.) When the head is returned to the erect position the liquid remains in the sinuses for the same reason that it remained in the nose before, namely, the small diameter of the ostia. Figs. 4 and 5 demonstrate why various sinuses normally fill to various depths depending upon the positions of their ostia and not upon the degree of vacuum or the amount of fluid present in the nose.

Necessity of Suction. It has been contended that fluids will enter the sinuses from the nose in the inverted position

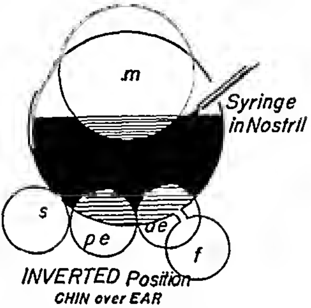


Fig. 3. The foregoing diagram in the inverted position, illustrating the failure of fluids, poured into the nose, to enter the sinuses unaided

without this change in air pressure, but I have not found this to be the case. In Fig. 6 the iodized oil may be seen lying in the nasal chamber, completely submerging the ostia of the sphenoids and the posterior ethmoid cells, but no drop has gained entrance to the cells. Fig. 7 shows the same head a moment later, after the application of suction. The oil has left the vault of the nose and has entered the sinuses.

It is conceivable that, owing to atrophy of the mucosa or to an extreme anatomical variation, an ostium may be of sufficient size to allow the interchange of liquid and air or that accessory sinuses may be so located as to permit this to occur, but I have not encountered such a case. The relations of the ostia to the turbinates and other contiguous parts is such as to render filling without suction difficult, even through a large ostium.

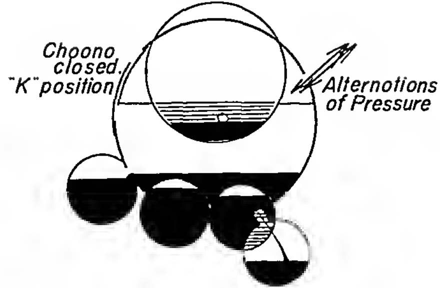


Fig. 4. Each sinus filled to the level of its own ostium by alternately exhausting small quantities of air from it and permitting fluid from the nose to replace the air.

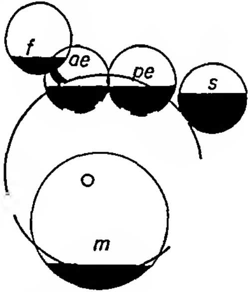


Fig. 5. The nose returned to the upright position, demonstrating why normal filling levels are not the *same in all sinuses.*

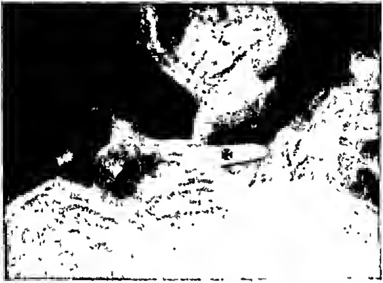


Fig. 6. Roentgenogram of the head in the inverted position, before suction. The radiopeque lies in the nasal chamber and does not enter the sinuses.

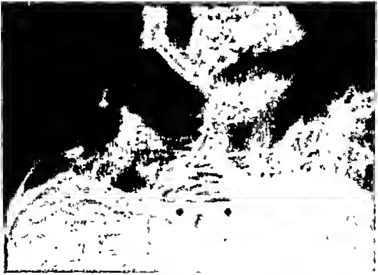


Fig 7 Same as Fig 6, after suction has been applied. The oil has entered the sinuses and only a trace remains to indicate its former position.

The filling can be accomplished with equal facility through the use of positive instead of negative pressure, but this method has disadvantages. Positive pressure may be the means of forcing air into slit-like potential cavities, such as the pharyngeal (cartilaginous) end of the eustachian tube. Furthermore, if the palate has not firmly closed the pharynx during the application of positive pressure, fluid will be spattered into the oropharynx, which disconcerts the patient and disseminates the oil. The use of vacuum is to be preferred because it permits the penetration of fluid only into cavities previously occupied by air.

THE DISPLACEMENT METHOD. The method of instilling the fluid is quite as simple as the following description indicates:

1. *The patient's head is inverted so that the chin and external auditory meatuses are in the same vertical plane.* (Fig. 8.)

2. *Fluid is instilled into the nose.* (Fig. 9.)

3. *Negative pressure (180* mm.*) is applied intermittently to one nostril, while a finger closes the other and the patient closes the pharynx by saying "K"* (Fig. 10.)

4. *The patient is returned to the erect position.* (Fig. 11.)

The time required is approximately one minute. Before laying him down, the patient should be told in a general way what is expected of him, so that he will be co-operative and unapprehensive, and so that no time will be lost in explanations and reassurances while his head is upside down.

In actual practice, the simplest means of placing the patient's head in the proper position is to have him sit in a treatment chair with a pivoted back, which drops to the horizontal position. The headrest should be removed. The operator is seated behind or beside the patient, so that when the patient is let

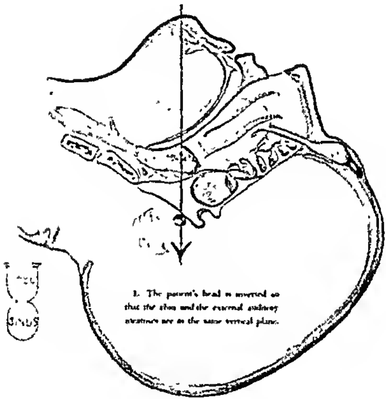
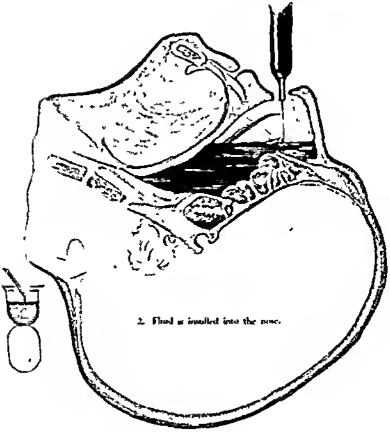
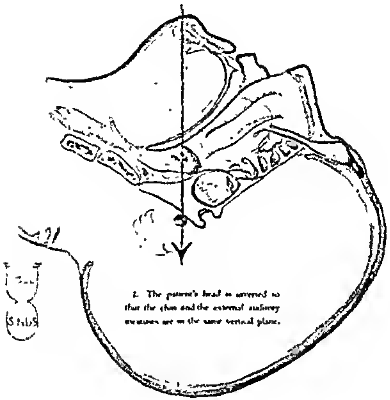

SINUS
1. The patient's head is inverted so that the chin and the external auditory structures are in the same vertical plane.

Figure 8



2. Fluid is instilled into the nose.

Figure 9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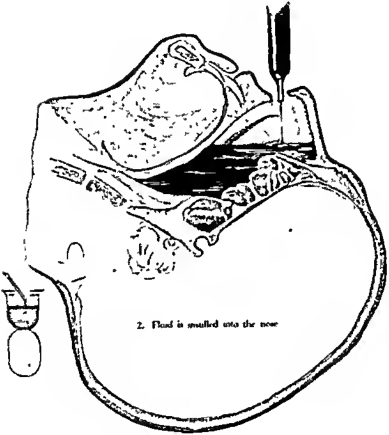

Figure 9

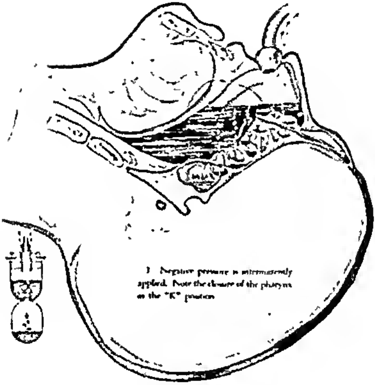
3. Negative pressure is intermittently
applied. Note the closure of the pharynx
in the "K" position.

Figure 10

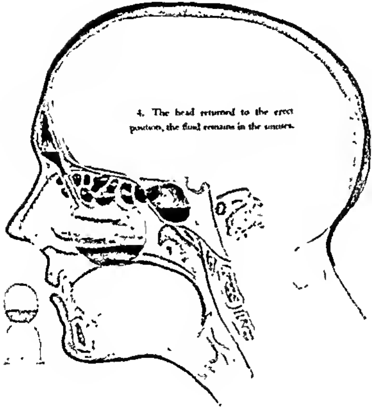
4. The head returned to the erect position, the fluid remains in the sinuses.

Figure 11

down into the horizontal posture his head rests upon the operator's knees. In this position one has complete control of the situation and can assure himself of the correct relation of chin and ear. (Fig. 12.)

If the chair is high off the floor, the operator stands at the side of the patient's head, from which position the filling can be best observed and the instrumentation best controlled.

It is well to have a towel on the operator's lap, not merely for esthetic reasons but in order that a corner of it will be quickly available in case a drop of fluid escapes from the upturned nostril or the syringe and threatens the eye.

The patient is instructed to open his mouth wide and to continue to breathe through it. This at once overcomes his desire both to swallow and to hold his breath, and assures him that he will not strangle. Many people close their pharynges automatically when they open their mouths; these need not be told to say "K" while the filling is going on. If the pharynx is open, the "K" position must be resorted to in order to close it.

Two to four mils. of fluid are now instilled into each nostril by means of a syringe. The fluid should be at or near body temperature for comfort, and should be injected smoothly to avoid tickling. It is more comfortable to the patient when the stream is directed along the floor of the nose than when it impinges upon the septum or the turbinates. Intermittent negative pressure should now be applied to one nostril through an olive tip, while a finger closes the other. This may be done by alternately inserting and withdrawing the olive tip from the nostril, but it is much better accomplished, with less discomfort to the patient, by opening and closing a hole drilled in the side of the tip for the purpose. Best of all is the standard Sorensen instrument illustrated in Fig. 22. Various tips are to be had

of the instrument makers. The suction should be released as soon as the vacuum of 180 mm. is obtained, which occurs in a fraction of a second, and about one second should elapse before it is reapplied to permit the fluid ample time to penetrate the ostium. This precaution should be observed especially when the more viscous oils are used. It is imperative that the suction pump have sufficient capacity to build up a vacuum of 150 mm. in one or two seconds.

After eight to a dozen alternations, the first instillation of fluid will have disappeared from the nasal chambers into the sinuses; more fluid is then instilled into each nostril, and the suction process repeated.

A total of eight mils. is sufficient for most purposes, but more may be required in individual cases. If more than four mils. is instilled at one time the fluid may enter the oropharynx and excite gagging.

On returning the patient to the erect position, he should be cautioned against blowing his nose. In the case of iodized oils for radiography, he should also be told not to stoop forward for any reason until after the exposures have been made.

Retention of Fluids. Fluids so instilled will remain in the sinuses for varying periods (twenty-four to ninety-six hours or longer), depending upon the mechanical features peculiar to the cells, such as size and position of ostia, sleeping position of the patient, extent of respiratory excursions, and the viscosity of the fluid. The significance of this retention time, from a diagnostic standpoint, will be presently considered.

By means of the supine position described for filling, oil may be made to penetrate into all of the nasal accessory sinuses to some degree. Obviously the sphenoidal and posterior ethmoidal cells, which in this position occupy the nethermost portions of

Fig. 12. The proper head position for displacement. The chin and the ear are in a vertical plane.

the nasal chamber with their ostia upturned, are ideally situated for filling, and receive the greater portion of the fluid. The anterior ethmoid cells are usually partly filled. The maxillary ostium, while relatively accessible, is, in the inverted position, near the most dependent portion of the cell, so that complete filling cannot take place. (See Figs. 10 and 11.) Enough fluid gains entrance, however, for most diagnostic and all therapeutic purposes. Peculiar difficulties are encountered in the case of the frontal sinus. Here the infundibulum is long and narrow, and bubbles of air are not easily disengaged from it, so that relatively small amounts of fluid gain access. However, if only a drop or two enters the sinus, that is sufficient

Fig. 13. When maxillary filling is of particular interest the patient *may be laid upon the orbit of the side to be filled* and the displacement done in this position. This brings the ostium of the antrum near its top.

to outline the nasofrontal duct and yield as much information regarding it as would a larger amount.

ADVANTAGE OF DISPLACEMENT OVER INJECTION. I can see little advantage in the displacement procedure for injecting radiopaque oils into the maxillary sinus when it is desired only to outline the cavity, as this is often readily accessible via the ostium. However, when information is sought regarding the patency of the normal opening, it is essential.

ANTRUM POSITION. As has been said, the ideal position for bringing about filling by means of the application of suction is that which places the sinus with its ostium uppermost. This is accompished in the case of the maxillary antrum by allow-

Fig. 14. The prone position for better filling of the anterior series of sinuses

ing the patient's head to rest squarely upon the orbit of the side to be filled. The nose should be allowed to extend over the edge of the table so as to be accessible. If the fluid is now inserted into the nether nostril by means of a syringe and retained there by closing the nostril with the finger, the intermittent suction can be applied to the upper nostril and the filling accomplished. (Fig. 13.)

PRONE POSITION. The frontal sinus can be penetrated in a similar manner, the head being placed squarely in the prone position with the nasofrontal suture and the external auditory meatus in a vertical plane. (Figs. 14 and 15.) Complete filling of the frontal sinuses has not been accomplished.

The antrum position and the prone position are now rarely used, although in selected cases they are the only ones in which a particular filling is possible, as for example the case of the osteoma of the frontal sinus illustrated on page 271.

The accompanying diagrams indicate the relations of the ostia to their respective sinuses, to the posterior margin of the septum, and to the anterior and posterior nares in the positions referred to. Shrinking of the membrane in the neighborhood of the ostia naturally facilitates the introduction of fluids and may be done preceding a treatment. This should be avoided, however, for twenty-four hours preceding the introduction of radiopaque oils for drainage estimation, as anything which tends to alter the natural states of the ostia will alter the results. Where it is desired merely to outline the cavity and not to observe drainage, preliminary shrinking may be employed to advantage.

IMMEDIATE EFFECTS. The patient should experience no ill effects following the manipulation, although there may be a momentary headache or giddiness immediately after the resumption of the erect position, owing to the congestion and the unaccustomed position of the head. It happens occasionally that a headache follows the first treatment. More frequently, an existing headache is relieved by it. I have seen a few instances in which headache followed each introduction; transient but of sufficient intensity to cause the treatment to be abandoned.

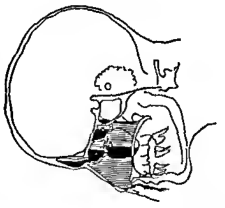

Fig. 15. Method of introducing oil in the prone position. In practice the patient's nose is grasped between the thumb and forefinger of the left hand to prevent the oil escaping.

Recurring headaches may be due to the irritating nature of the solution employed and not to the manipulation, in which case the solution may require diluting or may have to be abandoned. These headaches are further discussed on page 65.

Excessive negative pressure may also be to blame. Suction should be applied gently and not too suddenly. It should never be sufficient to cause pain during or after the treatment. Needless to say, there should be no epistaxis.

PRECAUTIONS. It is advisable to observe certain precautions. Patients with very high blood pressure should not be placed in the position required, nor be subjected to the negative pressure in the nose. I have also avoided any irrigation whatever in the early stages of acute nasal disease, both on account of the hyperemia which is readily induced at such times and because of the possibility of disseminating any infection which might otherwise remain localized. After twenty years, no accident of any nature has come to my attention, although the method has been employed by various operators in cases of known orbital dehiscences, pituitary tumors and the like.

Children's sinuses offer no particular obstacle to filling. On the contrary, they are readily filled and their average emptying time is shorter than that of the adult. Filling does not require the co-operation of the child. If it cries, its pharynx closes and the filling is easily accomplished. (See Chapter XVII.)

Some concern was felt, at first, in regard to the eustachian tube and the possibility of contaminating it with secretions from the nose. This proved to be groundless, however, as no solution has ever been found in radiograms to have penetrated the middle ears or even the tubes. The reason for this is obvious.

nd of the tube is cartilaginous, is surrounded
tissue and is normally in a collapsed state.
sseous portion of the tube is relatively long
t it is impossible for any air to escape from
en the vacuum is applied. As this is essential for the introduction of fluid, no penetration occurs. No case of infection of the middle ear has been shown to have resulted from this procedure.

Exception has occasionally been taken to the term "Displacement." It has been retained in the face of these objections because *it is essentially the displacement of air which permits the filling.* Where no air exists to be displaced, no filling occurs; obstructed ostia which prevent this displacement, prevent filling; the filling depends entirely upon the removal of air.

Possible Sources of Failure. Even in so simple a procedure as a displacement filling, one may sometimes fail. It has been found by experience in a large number of cases that some heads fill to better advantage if the extension is somewhat exaggerated. This was first recommended by Fraser as long ago as 1927, and is now practiced routinely by many laryngologists.

Parkinson[146, 147, 148] prefers to prop the patient's shoulders on a pillow and suspend the head laterally, the patient lying on his side. This also works satisfactorily. The details may follow the whim of the operator in this respect, so long as the sinus depends below its ostium, and the latter is well submerged.

Failure to bring the head into the required position may be due to the use of a chair or table unsuited to the requirements.

Neglecting to submerge all the ostia by using sufficient fluid before suction is applied, accounts for most of the failures to

fill antra properly. The statement is often met with, that displacement fills the sphenoid and posterior ethmoid cells but leaves something to be desired in the case of the others. If the nasal chamber is not completely filled before suction is applied, the maxillary ostia may never be submerged at all, or may be covered only for a single exchange of pressure, after which the sphenoids at the bottom of the chamber fill at the expense of the rest. It is good practice to fill the nasal chamber to the nostril before any suction is applied. Using a medicine dropper instead of an adequate syringe may account for poor anterior filling.

The poorest sort of suction device will serve to fill the sinuses after a fashion, which may lead the operator to be satisfied with something less than he should expect, or, on the other hand, may cause him to abandon the method.

Two really essential things should have his first attention. There should be available constant negative pressure which can be regulated to approximately 150 mm. (mercury), and the hole by means of which it is interrupted should be quite large, in order to insure prompt and complete fluctuations. The glass syringes with rubber bulbs which were originally used have the advantage of portability and initial cheapness, but for routine office work they are not very satisfactory. It requires considerable skill to time the patient's closing of his pharynx to the short period of suction which these syringes afford, and the bulbs deteriorate, reducing the suction materially.

The various water-tap devices and the electric pumps are most satisfactory. The tips used should have adequate openings and the thumbholes, as stated, should be large enough to permit complete equalization of pressure when the thumb is removed. Immediately continuous with the tip there should

be a glass reservoir for overflow. This last is of great assistance in treatment, as will be shown. The ordinary Sorensen goose-necked, glass tubed suction tip is used by most operators. Schillinger[154] has modified it for the special purpose of displacement.

CHAPTER III

APPARATUS

SUCTION DEVICES—ELECTRIC PUMPS—WATER PUMPS —VACUUM CONTROL—AUTHOR'S APPARATUS—LEMÉE'S APPARATUS—BULBS—SUCTION TIPS.

The armamentarium is extremely simple: a source of vacuum and a syringe. And yet, since the comfort of the patient depends somewhat upon the efficiency of the apparatus as well as upon the skill of the operator, its choice demands some consideration.

SUCTION DEVICES. The suction device is preferably some type of automatic pump producing constant and continuous suction. This apparatus has the advantage over hand-pumps and rubber bulbs of assuring a vacuum at the moment when the patient manages to get his pharynx into the "K" position. Many people naturally close their pharynges when they are placed in the exaggerated supine position; most of the rest quickly grasp what is required of them and make no difficulty of it. There remain, however, a precious few who regard the occasion as one for nasal and lingual, not to say vocal, gymnastics, and the occasional fleeting "K" which they attain calls for some virtuosity in the manipulation of the hand-bulb.

Of the electric pumps either the rotary or the cylinder type is satisfactory, although the former is to be preferred on account of its greater efficiency and smoothness of action. It is also quieter, which is of advantage in treating young children.

Neither of these possesses any real advantage over the old-fashioned water-faucet suction pump, which produces more than the required vacuum and can be regulated to a nicety.

I have encountered certain European pumps which build up the vacuum too slowly to be of use. The 150 mm. pressure should be reached in one to two seconds. The trap bottles supplied with some effective pumps are so large that too much time is required to reach the stipulated pressure. This may be quickly remedied by filling the bottle halfway, or more, with water.

CONTROL OF VACUUM. It is of the utmost importance, if the patient is to be spared a headache, that some means be provided of keeping the vacuum within bounds—that is, below 180 mm. of mercury. There is no necessity of providing troublesome and expensive gauges for this purpose, if the T-shaped connector shown at the end of the tubing in Fig. 16 has a large enough opening to permit immediate release of the vacuum when the finger is lifted.

If it be borne in mind that the vacuum is not required to do any more work than merely to liberate a small bubble of air through an ostium, there will be no danger of overdoing it to the point of discomfort.

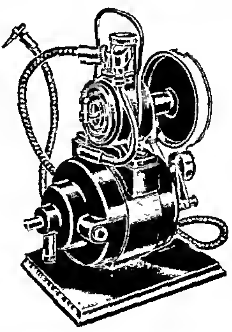

Fig. 16. Rotary type suction pump.

It is much more satisfactory to control the intermissions of suction by means of a finger hole in the tube line than by alternately inserting and re-

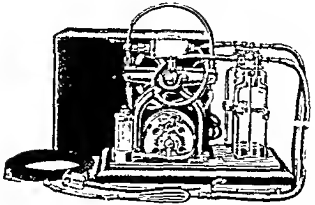

Fig. 17. Cylinder type suction pump.

moving the olive tip from the nostril. The latter method is not only cumbersome and likely to spill nasal secretions into the patient's eyes, but it releases the suction so slowly that, especially with an efficient electric pump, pain may be felt before the vacuum can be interrupted.

With the glass and rubber syringe shown in Fig. 19, the entire displacement can be effected. It is not recommended for routine office work where the much more satisfactory constant-suction pump can be available. It is useful chiefly at the bedside where the advantage of portability outweighs its faults. The rubber bulb of this syringe is designed to produce a vacuum of 180 mm. When it begins to deteriorate through age, boiling or contact with oils, it should be discarded.

Author's Apparatus. To replace the olive tips and glass tubes commonly used with suction pumps, I have devised a suction chamber and tip with which is combined a piston syringe in a single instrument. This is neither the simplest nor the most effective instrument for displacement, but was designed solely for the operator who works without an assistant, in order to do away with the necessity of changing instruments.

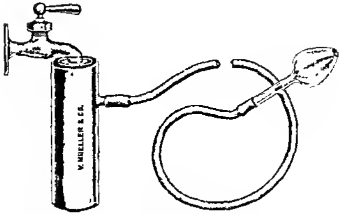

Fig. 18. Gray's water vacuum pump.

and refilling a syringe while the patient is in the recumbent position. The apparatus is a cylinder of metal seven-eighths of an inch in diameter and six inches long, the upper half of which constitutes the barrel of an 8-mil. piston syringe. The

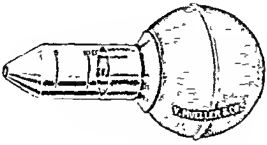

Fig. 19. The author's bulb syringe for introducing fluids and also making suction.

lower half is a vacuum chamber connected by a tap with the tubing of a suction pump, and terminating below in a detachable olive tip for adaptation to the nostril. The vacuum is con-

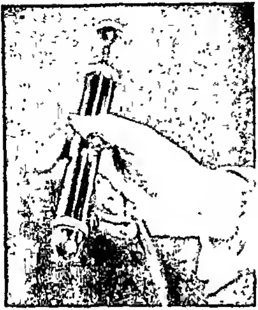

Fig. 20. The author's combined metal syringe and suction chamber.

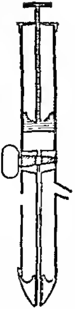

Fig. 21. Diagram of the metal syringe and suction chamber.

trolled by means of a finger hole in the side of the chamber. The cannula of the syringe extends longitudinally through the vacuum chamber and terminates within the opening of the olive tip. The flow through the cannula is controlled by means of a pet-cock at its junction with the barrel of the syringe. (See Figs. 20 and 21.)

In use, the olive tip is inserted into the fluid and the syringe is filled by withdrawing the plunger. The pet-cock is now closed to prevent spilling during the following manipulations. The pump is connected and started, and with the pump running, the instrument is laid at hand ready for use. The patient is now placed in the inverted position, the olive tip is applied to the nostril, the pet-cock is opened and 2 mils. of fluid is

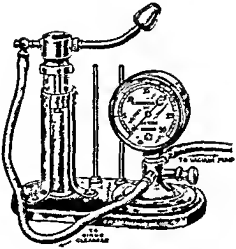

Fig. 22. Sorensen suction tip. The gauge is useful but not essential.

introduced in each nostril. (Calibrations appear on the push rod of the plunger at intervals of 2, 4, 6 and 8 mils.) The pet-cock is now closed, and, without removing the tip from the nostril, the intermittent suction is instituted by alternately closing and opening the finger hole at the side. The cock is opened once more, the remaining fluid is dispensed and the process repeated.

The instrument is held in the right hand, like a lead pencil, the index finger falling naturally over the finger hole. The plunger and the pet-cock are manipulated with the left hand.

For routine work, any ordinary 10-mil. syringe and a Sorensen nasal suction tip with a glass reservoir (Fig. 22) are recommended above other appliances.

Lately the author has assembled a portable kit containing an electric pump and all the required tips, bottles, syringes

and tubing, which is especially adapted to hospital and other bedside use. (Fig. 23.)

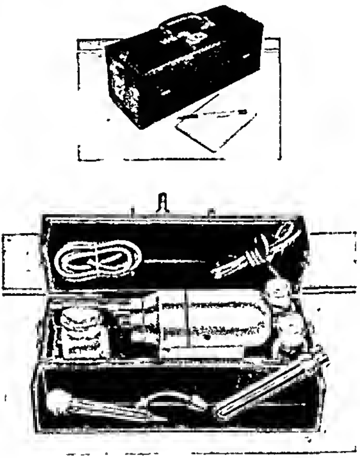

Fig. 23. Author's Complete Kit.

It may be suggested, in passing, that oils be not permitted to remain in contact with the rubber parts of any bulb syringes, as they soften the rubber and materially lessen the vacuum which they produce.

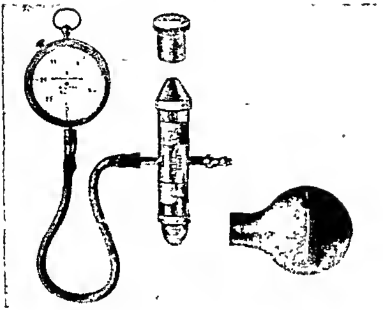

Fig. 24. Apparatus of LeMée.

LEMÉE'S APPARATUS.[100] The tip most commonly used abroad is one devised by LeMée. (Fig. 24.) It has the advantage of simplicity and a large finger hole for the control of the vacuum. It lacks the glass reservoir which is often extremely useful for the examination of material coming from the sinuses during the procedure.

The gauge is helpful in teaching students to confine the negative pressure to the required amount. The cap is applied to close the finger hole when the bulb shown at the right is substituted for the electric pump.

CHAPTER IV

PHYSICS AND PHYSIOLOGY

PHYSICAL PROPERTIES OF SINUSES—MECHANICS OF FLUIDS—NOSTRIL AND CHOANA—POSTURE—INEFFECTIVENESS OF SIMPLE SUCTION—PHYSICS OF MOVEMENT OF FLUIDS—VISCOSITY—CILIARY ACTION—SPRAYS AND DOUCHES—OSMOSIS—FUNCTION OF SINUSES—CILIA.

The manipulation and proper interpretation of fluids in sinuses must be based upon physical principles which it will repay one to review.

At first glance, the problem appears to be a very simple one, as the conditions which surround it are certainly not complex; but the forces which control the movements of the fluids in question are numerous and, which is more important, variable. Their resultants are not always obvious.

The fluids concerned are air, normal secretions, inflammatory exudates and solutions employed for diagnosis and treatment.

The physical factors which determine their behavior are pressure, gravity, viscosity, surface tension and temperature.

MECHANICAL FACTORS. Before proceeding to the matter of fluid currents, it is necessary to examine thoughtfully the physical characteristics of the sinuses themselves, of their ostia and of the nasal chamber and its outlets.

The sinus is essentially a rigid-walled cavity containing air. The rigidity ol its walls, hence the invariability of its air capacity, is especially to be remembered in all problems involving air pressure, for although the lining membrane may be soft and thick, and yielding to the touch of the probe, the limiting

bony wall obviously does not yield to air pressure, positive or negative, and prevents the enclosed soft parts from doing so.

The actual air capacity of the sinus, on the contrary, is determined by the condition of the membrane, which determines also the relative patency of the ostium. The important thing is that whatever the air capacity of the sinus may be at the moment (determined by the thickness of the membrane), it cannot be immediately influenced by positive or negative air pressure. That is to say, suction as ordinarily applied with the idea of emptying sinuses cannot cause its walls to yield and to extrude secretions, and therefore fails of its purpose. Such changes must be brought about through vascular or lymphatic mediation, and are therefore relatively slow.

NOSTRIL AND CHOANA. The flow of air through the ostia is determined by their size and the degree of pressure applied, and in the process of respiration the latter is influenced to a very great extent by the relative sizes of the nostril and the choana, a fact which has received little attention.

Assuming that there is such a thing as a normal respiratory current in the nose which maintains normal positive (expiratory) and negative (inspiratory) pressures at the ostia, it is obvious that these pressures increase both in their positive and negative phases as the nostril decreases in size. In like manner, the extremes, both positive and negative, are decreased as the choana narrows (choanal index). Whether the narrowing occurs at the nostril or at the choana, the current of air in the *opposite nasal chamber increases, with a resulting increase in* the extreme pressures at the ostia. The pressure variation in the sinuses is of the order of −6 mm. to +6 mm. water, as measured in the antrum by Braune and Clasen,[19] or −50 mm. to +35 mm., respectively, in forced inspiration and expiration. (Fig. 25.) Restrictions of the nostril, of course, result in some degree of forcing.

Complete blocking of the choana from any cause (atresias, tumors, adenoids) naturally stops all air currents through the ostia so that no interchange of gases takes place there excepting a negligible amount through diffusion.

In the presence of a complete congenital choanal atresia, the sinuses may or may not be infected, whereas, in the case of the acquired postnasal blockades sinus infection is the rule. Tubal infections also commonly accompany the latter, whereas in a case of congenital absence of the nose, including sinuses, recently observed, the ears and the hearing were normal. We leave to the pathologist the task of reconciling these findings.

Too obvious to require more than passing mention are the effects of adjacent structures — septal deformities and turbinates—upon the patency of the ostia.

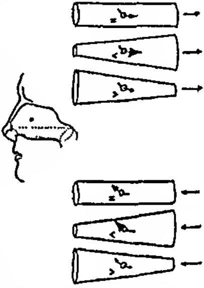

Fig 25. Diagrammatic representation of the relation of pressure changes at an ostium to variations in the sizes of the nostril and the choana. The arrows in the small drawings indicate the direction of flow, and their sizes the relative pressures.

POSTURE. Posture merits some attention. The sphenoid and the maxillary sinuses are commonly regarded as the poorest drained, in the erect position. The maxillary sinus receives secretions from frontal and anterior ethmoid cells, owing to the peculiar configuration of the unciform process and the hiatus semilunaris, and to its own dependent position. The sphenoid has been suspected of receiving exudates from the

posterior ethmoid cells in certain positions, but it is difficult to see how these positions might be assumed in the course of the individual's normal pursuits. Ciliary action also is effectively directed against it in this region.

When there is some impairment of ciliary function, sleeping postures may have some importance. The patient who sleeps habitually on his right side offers his left antrum excellent gravity drainage, while the right is never so drained. The one who sleeps always upon his back depends entirely upon respiratory currents and cilia to empty his sphenoids. The sphenoid cavity with a pneumatized pterygoid process presents the most difficult situation for postural drainage. However, after observing a great many such cells filled with opaque oil, one is forced to the conclusion that in a healthy sphenoid, posture plays a minor role in drainage, for the most tortuous pterygoid pouch empties itself as readily as any other cell in the nose and much more quickly than a diseased cell having natural gravity drainage.

The patency of ostia should be considered relative to the gases and liquids which are to pass through them, and which differ widely in their physical properties. Beside the passage of the normal inspired air, the chief concern with the effects of air pressure arises in regard to certain forms of treatment.

Ineffectiveness of Simple Suction. The simple application of suction to the nostril with the patient in the upright position is an ineffectual means of emptying the sinus, unless its ostium lies at its very bottom and the sinus contents are fluid.

To remove a fluid by suction or by postural drainage, from a rigid chamber through a small opening, two conditions are requisite: its viscosity must be relatively low, and it must completely cover the opening. If the viscosity or the surface ten-

sion be high, the exuded drop will not fall away from the ostium, but will be drawn back into the sinus when suction is released. (Fig. 26, B.) If the submersion of the ostium is not complete there can be no effect produced by suction on the contained fluid; hence the uncertainty of depending upon simple suction to produce pus as a diagnostic measure.

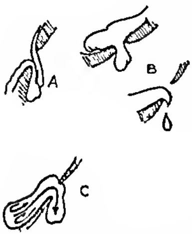

Fig. 26. The behavior of viscid fluids passing through ostia.
A. Secretions from all sides converge and meet at the ostium to be extruded in the form of a ropy strand.
B. When suction is made a drop is extruded. If the fluid is too viscous for the drop to separate from the main mass, it is drawn back into the sinus when pressure is released, otherwise it falls away.
C. The motion of viscid masses through the ostia is most rapid at the center of the mass, the periphery moves relatively slowly if at all.

Physics of Movement of Fluids by Suction. Grant for a moment that the position of the ostium and the nature of the fluid are favorable for its removal by suction, still other physical restrictions interpose themselves. According to Boyle's law, the volume of a gas varies inversely as the pressure, the temperature remaining constant.

$$pv = km$$

where p is the pressure, v the corresponding volume of a given quantity of gas, m the mass of the gas, and k a constant factor of proportionality.

Assume that a given cell has an air capacity of one millilitre, that it is half filled with a thin fluid and that its ostium is at the bottom, in the optimum position. In order to force out the $\frac{1}{2}$ mil. of fluid, the volume of the $\frac{1}{2}$ mil. of air will have to be doubled. To accomplish this the pressure outside the cell must be reduced by $\frac{1}{2}$ atmosphere—a vacuum of 380 mm.

of mercury,—which is far beyond the limit of safety in the nose. What occurs in practice is, of course, that a very much smaller amount is removed at a time, by a very much lower vacuum often repeated. During an instillation by displacement, the same thing occurs but the flow is in the opposite direction.

If the pressure in the nose be reduced by, say, 1/6 of one atmosphere, the volume of enclosed air will be increased to $6/5 \times \frac{1}{2}$ mil., or .6 mils., an increase of .1 mil. Therefore, .1 mil. of fluid will be forced out. Larger and smaller cells extrude amounts in exact proportion, not to their size, but to the volume of air they contain.

Therefore, if the contents of the cell are sufficiently fluid, and the head is in the proper position, repeated gentle suction will remove them a drop at a time. Under proper conditions the excursions of respiration (which Braune and Clasen[19] estimate produce in the maxillary sinus an average fluctuation of 12 mm. of water) are sufficient to withdraw fluids from the sinuses. One has frequently noticed this in experimenting with solutions introduced into the sinuses by displacement—in fact, *many antra may be emptied of pus in this manner without resorting to puncture.* In some instances the experimental solutions, which were flavored for ready identification, were pumped out by the respiratory excursions several hours after introduction, when the head was suddenly placed in a favorable position.

VISCOSITY. The subject of viscosity receives scant attention in most medical texts. In gases, liquids and plastic materials, the term viscosity is applied to the friction between the component molecules of the substance as they pass over one another when changes in the shape of the mass occur. Exudates commonly encountered in the sinuses vary widely in their compositions and in their viscosities, and the latter are usually high,

compared with the viscosities of blood plasma and the normal secretions. The sinus contents are apt to be rich in mucin, the surface tension is high, and the mass changes its form slowly.

One must not conceive of the pus in a sinus as being necessarily a thin fluid which readily seeks its lowest level. Instead, it often clings tenaciously to the walls, especially if these are irregular and divided by septa. Changes in the posture of the head may not cause it to shift its position in the sinus unless the new position is maintained for some time. When patients whose nasal fossæ are literally filled with pus lean forward, the pus does not escape from the nose as does, for instance, the thin fluid of vasomotor rhinitis. No more does the momentary shifting of the patient's head during the application of suction bring about a readjustment of the secretions within the sinuses sufficient for effective evacuation.

One has observed that much of the pus which is evacuated from the nasal fossa by simple suction has been dislodged from the vault of this chamber itself, or from the vault of some meatus where it was hidden, and not from within the sinus as was at first supposed.

The viscosity of a substance is measured by the tangential force on a unit area of either of two horizontal planes at a unit distance apart required to move that plane with unit velocity in reference to the other plane, the space between being filled with the viscous substance.

The ratio of the force required to move the one surface parallel to the other, to the velocity of such motion (or "shear") is known as the coefficient of viscosity. It is expressed by the symbol η

$$\eta = \frac{\text{F (force)} \times \text{S (distance between faces)}}{\text{V (velocity)}}$$

Comparative viscosities are often expressed in terms of the velocity. They are recorded in seconds, compared to the viscosity of water, designated as one second.

It follows that in the case of fluids lying on inclined planes, such as secretions in sinuses, the value of V is low where the coefficient of viscosity is high, as the moving force F is limited to the weight of the drop itself.

In subacute inflammations, and still more in chronic ones, exudation is slow, and the coefficient of viscosity of the secretion is high. The movement of the mass under such conditions is that of a semisolid rather than a liquid.

The movement of a thick stream making its way through an ostium is not unlike that of emulsions passing through capillary tubes. The center of the mass moves at the highest velocity, the periphery scarcely at all.

ACTION OF CILIA. It has been shown[170] that cilia can and often do function in chronically infected sinuses. This introduces many variations in the movement of mucus (which Yates[234] describes as being rolled over and over), influenced somewhat by the individual conditions of nasal chambers. In unobstructed, healthy noses, ciliary streaming effectively empties every crevice, gravity (hence posture) having no effect.

SPRAYS AND DOUCHES. A word may be said here in regard to sprays and douches and the solutions employed for this purpose. Sprays follow the passages from nostril to choana which offer the least resistance to the air. The globules are deposited upon the exposed membranes. If there is a free nasal passage, the spray follows the inspiratory pattern of air currents and none of the vapor enters the meatuses or the sinuses.

In irrigating or douching the nose, the amount of fluid to enter the sinuses must depend upon the amount of vacuum pro-

duced in it, intentionally or fortuitously, during the process, as any penetration of fluid must be attended with the displacement of air. The simple snuffing of fluids is attended by some negative pressure (−50 mm. Braune and Classen, above), and if a droplet of fluid covers the ostium at the moment that the vacuum is released it will be drawn into the sinus. Larger amounts of fluid may be made to enter a sinus by supplying the necessary posture and fluid, and displacing the contained air.

OSMOSIS. Of the osmosis of colloids, as it affects sinus problems, only this need be said, that upon it depends the secretion within the sinuses, which determines the fluidity of their contents. And further, that as colloidal systems (which include both the protoplasm of the living membrane and the products of inflammation which accumulate upon it) are especially sensitive to electrolytes in solution, it should repay us to inquire more closely into the action of salts in various concentrations with a view particularly of improving the conditions of drainage. Digestive ferments have occasionally been employed for this purpose.

Temperature varies within relatively small limits in the sinuses, and its effects from a purely mechanical standpoint are negligible.

As has been said, each sinus is a rigid walled polyhedral air cavity, communicating with the outer air through a relatively small opening. These openings occur in one of three positions: First, at the bottom, as in the frontal sinus; second, at the side, as in the ethmoids and sphenoids; and third, atop, or nearly so, as in the antrum (Fig. 27). These three types present three mechanical problems, and do not respond alike to the physical agents such as irrigation and suction, applied from without.

The ostia are normally patent and permit the free diffusion of fluids, but they may be wholly or partially occluded in various ways. Furthermore, some ostia which are swollen shut and do not permit natural ventilation may still yield to pressure from within or without.

When the ostia are occluded, positive and negative pressures may be maintained in the sinuses for only short periods. They tend to become rapidly equalized by the absorption of some of the enclosed air or the reactions of hyperemia, increased secretion, and even exudation.

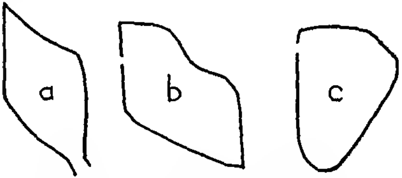

Fig. 27. Diagrams showing the relations of ostia to their sinuses. A, frontal and ethmoidal; B, sphenoidal and ethmoidal; C, maxillary.

Theories of Function of Sinuses. Much as is known about the behavior—and especially the misbehavior—of the nasal sinuses, their proper function remains a mystery.

A mere enumeration of the theories regarding the sinuses must suffice here. Skillern[193] assembled them in this order:

1. Remains of rudimentary structures which in lower forms served as adjuncts to the sense of olfaction. (Ingersoll and others.)

2. Adjuncts to olfaction through assistance in distributing air. (Braune and Clasen.)

3. Means of lightening the bones of the skull, to maintain balance. (Vesalius and many others.)

4. Resonators of the voice. (Spiegel and Voltini.)

5. Humidifiers, as an adjunct in moistening the inspired air.

Since the sinuses surround the nasal chambers much as the water jacket surrounds a combustion engine, it is entirely conceivable that these cavities may act as insulators to protect sensitive adjacent structures from the low temperatures to which the nose, owing to evaporation and outside temperatures, is subject. The tremendous sinuses of the giraffe lend color to this theory.

To each of these theories such cogent objections are advanced as to render none of them completely tenable.

I once added another to the list,[157] briefly to the effect that sinuses are formed by the cleavage of bones of the face and head, necessitated by an unequal development of their respective parts, after ossification has set in.

Large sinuses keep the head afloat when an air-breathing land animal takes to the water. Picture a giraffe attempting to swim without them!

Though the ultimate purposes of the sinuses are not clear, much is known regarding the general physiological processes which take place in and about them, and these are of importance in diagnosis and treatment. To begin with, the normal sinus is lined with a low, stratified columnar epithelium, completely covered with cilia. Ciliary action was recognized long before the nature of epithelium itself. It was described by A. de Heide (1683) and A. von Leeuwenhoek (1695) in mollusks and later in the vertebrates. We are not concerned here with the development of the knowledge of ciliary action, particularly since it is not perfectly understood at this day. Certain determined facts, however, interest us.

CILIA. Cilia are hairlike bodies on the surface of certain epithelial cells. In the sinuses they measure 7-8 μ in length. Such diversity of opinion exists as to the essential mechanism by which cilia move and co-ordinate their motion until it becomes a surface wave, that no attempt is made to discuss it here. Essentially the motion consists of two phases, an "effective stroke" in one direction by which work is done and a "recovery stroke" in the opposite direction during which the cilium regains its original position. The wave produced by the co-ordinated movement of the effective strokes is propagated along the surface of the epithelium and maintains currents in the surface mucus which conduct microscopic bodies toward the ostium. For brief but comprehensive resumés of the subject, the reader is referred to Gray's little book[85] on "Ciliary Movement," and the author's "Essays on the Physiology of the Nose."[172]

It has been generally held by cytologists that the activating mechanism of the cilia, whatever its nature, is inherent in the cell and is not controlled by nervous stimuli, although McDonald and his associates[151] describe experiments with the pharyngeal membranes of the frog in which the speed of the ciliary wave was controlled by sympathetic and parasympathetic stimulation. Wenner points out that these effects may have been due to chemical changes, notably the increase in calcium liberated by the nerve stimulation.

Ciliary activity is absolutely dependent, for its function, upon a surface film of moisture, being retarded and finally paralyzed by progressive dehydration. Cold has a similar effect, though complete cessation of motion occurs only at temperatures around 10° C, and unless actual freezing takes place activity is rapidly resumed as the temperature approaches 20° C.

The practical value of these observations lies, naturally, in their application to the particular surgical problem in hand, and to my mind, the most important of them in so far as one's conception of infection and its chronicity is concerned in this: The extent and effectiveness of ciliary propulsion are greatly modified by excess of moisture which creates gravity currents flowing over and neutralizing ciliary currents. These currents are determined by the amount and viscosity of the fluid and the topography of the surface. Which, translated into the language of the laryngologist, means that so long as the foreign body is microscopic in size (bacterium) it can be propelled toward the ostium by the cilia. But once infection

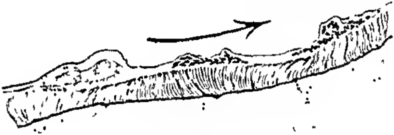

Fig 28. Diagram of ciliary wave propulsion, and size of cilia relative to erythrocytes, bacilli and cocci in the mucous streams upon the surface. An antrum drawn to the scale of these cilia would be 150 feet high.

sets in and exudation occurs, the cilia, though possibly still active, fail to cope with the situation.

Under conditions of vitamin A deficiency in the diet the ciliated surface cells slough away, giving place to a cuboidal type of cell and permitting bacteria to invade the host.

For convenient visualization of the situation, multiply all the measurements of these minute structures by 100, and

regard a 30 mm. antrum as a ten foot room. The ostium in proportion becomes an eight inch ventilator near the ceiling. The ciliated epithelium in such a chamber would be represented by a fine velvet wall covering, having a pile not over 1/40 of one inch in thickness.

The length of the cilia is roughly comparable to the diameter of a red blood corpuscle, micro-organisms which are considerably smaller being readily carried along in the stream maintained by the ciliary wave. (Fig. 28.)

By peeling off sections of ciliated epithelium, and permitting them to propel particles of known weight up an inclined plane, Bowditch[18] estimated the amount of work done by the cilia. He stated this to be of the order of 7 gram-millimeters per minute for each square centimeter. The rate at which cilia perform work increases with increasing load until a maximum is reached, after which the rate rapidly declines, due to fatigue.[129]

The pathways along which the cilia of the nose direct drainage from the sinuses to the pharynx have been described by Yates[231] and others,[152] but do not immediately concern us. The lymphatic drainage also presents no peculiarities from a physiological standpoint. It is chiefly by way of the retropharyngeal nodules.[141] Mucous glands are less numerous in the membranes lining the sinuses than in the nose. The film of mucus covering the healthy sinus wall is extremely thin—in fact, just sufficient to maintain physiological ciliary action, and no more.

The author has observed that cilia in the frontal sinuses of dogs propel oils of the viscosity usually employed in opaque injection, toward the ostium with almost the same facility and speed as carbon granules are propelled. Oils deeply stained with fat soluble chlorophyll were dropped through

capillary pipettes into the sinuses in such positions that propulsion uphill was required to reach the ostium. The green color was invariably seen to streak toward the ostium and in no other direction. It is thus extremely unlikely that other agencies beside ciliary action were responsible for the motion.

Similar streaming of radiopaques can often be noted in films of the human antrum.

CHAPTER V

ANATOMICAL CONSIDERATIONS

SIZE OF THE NASAL CHAMBER—SHAPE OF THE NASAL CHAMBER—THE OSTIA—CUBICAL CONTENT OF THE SINUSES—FACTORS WHICH INFLUENCE FILLING—EUSTACHIAN TUBE.

In the practice of displacement are encountered certain anatomical considerations which do not enter into the usual nasal examinations and treatments.

SIZE OF THE NASAL CHAMBER. One of the more important of these is the size of the nasal chamber. To attempt to express this in figures is futile, as variations in the dimensions are great, and the bulk of the turbinated bodies varies.

"The following may be taken as representative dimensions based upon a large series of specimens studied by [Schaeffer][182]: The greatest sagittal diameter, measured from the most prominent part of the naris along the floor of the nasal fossa to the dorsal border of the hard palate, is 74 mm., while the extreme sagittal diameter measured along the roof of the fossa is but 35 mm. or less. The greatest height (vertical diameter) is found by dropping a perpendicular line from the ventral third of the cribriform plate of the ethmoid to the floor of the nasal fossa—averaging from 40 to 45 mm. The nasal fossa is a mere cleft in the coronal or frontal plane (width) along the cribriform plate (*roof*)—*3 mm.* or less. The widest part of its floor varies from 12 to 23 mm., measured at the greatest lateral expansion of the inferior nasal meatus. The width of the floor in advance of the knee of the inferior nasal concha is much reduced—4 mm. or less. It is well to

remember that after the normal point of constriction is passed the inferior nasal meatus is much more roomy."

For purposes of displacement one is interested chiefly in the cubical content of the fossa, all of which lies beneath the horizontal plane of the nares when the head is in the ear-and-chin-vertical position. (See Fig. 8.) The amount of fluid which may be introduced into each fossa without overflowing is an important consideration, as the excess promptly settles in the patient's eye. It has been found to be in the neighborhood of 10 mils. Schaeffer's over-all measurements, here quoted, indicate the capacity of the fossa as about 30 mils. from which the bulk of the turbinated bodies and septal irregularities must be deducted. In filling sinuses not more than 5 mils. is injected into each fossa at one time, to prevent spilling when suction is applied. Three mils. or less is better in average noses.

For practical purposes, it is not feasible to lay down exact rules for the proper amount of fluid to be used. In principle it should be stated that as the ostia must be submerged, the amount of fluid which just misses spilling out when suction is applied, should be used. Less than this may fail to reach the higher lying maxillary and anterior ethmoid ostia. This accounts for the statement sometimes encountered, that the method is excellent for the posterior cells, but less so for the antra.

Shape of the Nasal Chamber. The nasal chamber is roughly rhomboidal in sagittal outline and triangular in section, the apex being at the cribriform plate, the base of the triangle the nasal floor. When the head is inverted to the chin-and-ear-vertical position, the pocket formed by the cribriform plate of the ethmoid and the face of the sphenoid becomes nethermost in the fossa. (Fig. 29.) These surfaces meet at

an angle of about 100°. In this position the nasopharyngeal wall slopes abruptly upward to the oropharynx, permitting the complete filling of the nasal chamber through the nostril without overflowing into the pharynx and gagging the patient. The extent to which it is possible to fill each sinus depends upon the position of its ostium relative to the sinus itself and not relative to the nasal chamber.

THE OSTIA. The facility with which each cell is filled depends somewhat upon the relative size of ostium to sinus, as well as the actual size of the ostium itself. In the inverted position all ostia lie below a horizontal line drawn through the orifice of the eustachian tube and therefore also below the level of the pharyngeal outlet. (Fig. 8.)

In this position the natural opening of the maxillary sinus may be near the extreme bottom of the sinus. If this is the case, very little fluid enters it; to be exact, only that amount which replaces air evacuated at the last application of suction. If the ostium is not precisely at the bottom, whatever portion of the cell lies beneath it can be filled. The entire frontal sinus lies below the level of its ostium in this position, although the nature of the inlet is such that filling is relatively difficult.

About one half of the ethmoidal capsule and two-thirds of the sphenoid lie beneath their respective ostia, *in the inverted position*, and the cells are filled in those proportions.

CUBICAL CONTENT OF THE SINUSES. The capacities of the sinuses have been found to be extremely variable.[119, 181]

The frontal varies from	1 mil. to 23 mils.	Av. 12 mils.
The maxillary varies from..........	9.5 mils. to 20 mils.	Av. 14.75 mils.
The ethmoid capsule varies from	.8 mils. to 16 mils.	Av. 12.2 mils.
The sphenoid varies from..........	.5 mils. to 30 mils.	Av. 7.5 mils.

The average *available* filling capacity in the *inverted position* has been determined by the author to be approximately as follows:

Frontal	1 mil
Maxillary	3 mils.
Ethmoid, anterior	2 mils.
posterior	3 mils.
Sphenoid	4 mils.
Total (one side)	13 mils.

This is graphically represented in Figs. 10 and 11.

FACTORS WHICH INFLUENCE FILLING. The anterior series of sinuses are filled less readily than the posterior for

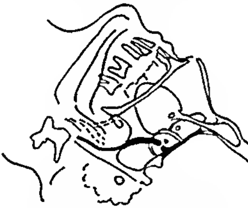

Fig. 29. Diagram accentuating the face of the sphenoid and the cribriform plate of the ethmoid, which constitute the floor of the nasal chamber in the inverted position.

still another reason, namely, the position of their ostia in the middle meatus. The inverted middle turbinate delimits a narrow groove which accommodates only a very small amount of oil at one time; and at the same time may act as a flap valve, if it is at all engorged or otherwise enlarged. It may be necessary, on this account, to resort to shrinking of the middle tur-

binate if more complete filling is required. The narrowness of the vault of the middle meatus has no effect, however, upon the emptying time, unless it exists to a pathological degree.

The ostia themselves vary greatly in shape as well as in size. As a rule, these are ovoid apertures, and are ordinarily patent. They may be elongated to mere slits, or they may, depending upon the distance of the cell cavity from the nasal chamber, be actual tunnels as in the frontal sinus.

The sphenoid mucosa, for example, is characteristically thin, its tunica composed chiefly of parallel elastic elements laid closely together and bound firmly to the underlying bone. It contains very few glands. The nasal mucosa, on the other hand, is many times thicker and is permeated with vascular channels and glandular elements.

The two sheets of mucosa do not lose their identity at the ostium, and do not merge, but lie definitely side by side until they reach the edge of the ostium, the only tissue which passes uninterrupted through the ostium being the epithelial layer. The underlying bone comes to a sharp edge, around which no structure can be seen to pass from nose to sinus (or the reverse) and against which no structure can impinge in case of swelling.

The tunica propria of the sinus can scarcely be said to enter into the formation of the ostium at all, as it terminates abruptly *somewhat short of the margin.* The ostium lining is thus a part of the nasal mucosa which exhibits two or three small folds just at the opening, and which is here supplied with more than the usual number of mucous glands and venous spaces. The connective tissue elements are loosely arranged.

No nerve elements of any consequence were found here. A few fibers were encountered, usually in close relation to the

arterioles, but in no case were they large enough or so placed that engorgement of the vessels or edema of the tissues could have brought them under pressure against bone, especially against the bone margin of the ostium.

Insofar as one may be permitted to deduce functions from structures, the following suggest themselves with a reasonable degree of likelihood, in the case of the sphenoid.

1. The connective tissue stroma and the intercellular spaces are so arranged that swellings probably take place into the nose and into the sinus respectively, and that only extreme tension can cause the tissues to encroach upon the ostium in such a way as to close it.

2. That in case of inflammation the nasal side of the ostium expands much more than the sinus side because of *(a)* the loose arrangement of tissues, *(b)* the disposition of the blood spaces and *(c)* the location of the folds and furrows in the mucosa.

3. That considerable engorgement or actual hyperplasia is required to close the ostium completely.

4. That the ostium, as such, is probably not involved in the causation of headache.

5. That since the ostium is composed chiefly of nasal, and not sinus elements, and is supplied chiefly by nasal arteries, application of constrictors, such as ephedrin, to the neighborhood of the ostium should usually open it.

Although pathological processes may distort the ostia into all manner of orifices, valves and crevices, I have been unable to uncover a single authenticated case of complete closure—that is, one in which the epithelium of the inside was not continuous with that of the nose, through some actual or potential passage.

As the extended retention and gradual emptying of fluids is a fundamental advantage of the displacement method, the continued effect of these fluids upon the ostia and the structures which pass through these bony openings is of primary interest.

From the ostia, ciliary action and the natural contours of the nasal chambers, direct fluids ultimately into the esophagus. One is struck by the similarity of these courses to the pathways through which viscous fluids would naturally gravitate in passing over the contours in question, without the intervention of the cilia. In fact, they may be demonstrated to do so in a wet anatomical preparation.

The counterpart of this anatomical conformity to pure physical patterns is the streamlining of the nasal turbinated bones to the respiratory air currents. It has been observed that the middle turbinates conform to the currents which are normally the result of the shape of the nasal fossa and its orifices; so that when these bones are removed there is no appreciable change in the current patterns.

EUSTACHIAN TUBE. The auditive (eustachian) tube requires mention here only to point out that it does not enter into the question of displacement. Owing to the elastic nature of its pharyngeal end, to its length, and to the relatively small air content of the ear, no air is displaced from it and no fluid enters it, no matter in what position the head may be placed.

CHAPTER VI

PATHOLOGY AND THEORY OF TREATMENT

THE MUCOSA — STRUCTURE — REACTIONS — POSSIBLE CAUSE OF CHRONICITY—CHRONIC SINUSITIS—INDICATIONS FOR EXENTERATION—INFLUENCE OF TREATMENT ON OSTIA—SOLVENTS AND DILUENTS—ASTRINGENTS AND VASO-CONSTRICTORS.

Although the mucosa which lines the nasal sinuses resembles, in the general structure of its coats, the neighboring mucosa of the nose, still there are certain differences which should influence the rationale of treatment in each case. Treatment of any kind has for its ultimate purpose the restoration of function and wherever possible, of structure as well. As regards function, one must be satisfied in the present state of knowledge with the removal of conditions conducive to the absorption of toxins and the production of pain. This means in most cases the removal of infection and the establishment of ventilation and drainage.

Restoration of structure within the sinus is important only in as much as it influences function, since neither gross mechanical nor cosmetic requirements exist here. In order to determine then, the type of treatment required and the extent to which it shall be carried out, one considers briefly the pathology of sinus membranes.

THE MUCOSA. The mucosa of the sinuses is continuous, layer for layer, with that of the nasal fossæ and differs from it only in the relative prominence of certain of its elements. In general it is much thinner than the nasal lining, ordinarily between ½ and 1 mm., contains relatively few glandular elements and is not erectile. The mucosa consists of an outer layer of stratified columnar epithelium which is generally cili-

ated. The extent to which cilia occur appears to vary in individuals. This is probably the direct reflection of the patient's environment and previous nasal condition. A nose which has seen much abuse, either through a lifetime of too dry and too dusty atmosphere, or through frequent infections, is apt to be devoid of cilia in its more exposed areas. Regions of the mucosa which bear the brunt of over-ventilation occasioned by constrictions elsewhere are likewise affected. In any case, ciliary activity is more continuous and effective in the more protected meatuses than on the exposed margins of the turbinates.

Fig 30. Photomicrograph: mucosa of the human septum, showing the transition from the respiratory type of epithelium, left, to the olfactory type, right. Note abundance of glands. (From Proetz, Applied Physiology of the Nose, 1943, p. 80).

Beneath the epithelium is a very thin basement membrane whose identity is sometimes lost in the superficial structures of the thin tunica propria. This tunica blends again almost imperceptibly with the periosteum to which it is so firmly attached

as to be frequently inseparable from it. This is especially true in the frontal and maxillary sinuses and to a lesser degree in the ethmoidal labyrinth and the sphenoidal sinuses.[151] There are relatively few elastic fibers as compared with the nose and few mucous glands. In the maxillary and sphenoid sinuses the glands are more numerous in the region immediately surrounding the ostia.

Fig 31. Photomicrograph: mucosa from the ethmoidal sinus. Note the membrane is almost devoid of glands. (From Proetz, Applied Physiology of the Nose, 1943, p. 161).

In comparing the structure and behavior of the various sinuses in health and disease, one is struck by the many similarities existing between the maxillary and the sphenoidal sinuses which they do not share with the other cells. In the character of their membranes, the location of their ostia, their general contours and the variable effects which posture may have upon their drainage, they are much alike. Their general anatomical simplicity, combined with their relative accessibil-

ity, renders them more amenable to treatment than either the frontal cells or the ethmoidal capsule and has accorded them much wider interest and publicity.

Considering their intranasal inaccessibility, it is fortunate that the frontal cells are posturally well drained and cause relatively little trouble. The ethmoids, however, with their ramifications and their lamellæ complicating both drainage and treatment, deserve more attention than they have received.

In a membrane devoid of erectile tissue and poor in reticular elastic fibers, one should expect *a priori* a relatively restricted propensity toward swelling. This thin delicate membrane, however, has shown at times astounding susceptibility to edema in allergic individuals, amounting practically to obliteration of the sinus cavity (Figs. 110 and 136); and a similar edema may undoubtedly accompany inflammatory conditions in non-sensitive individuals. The statement that rapid thickening occurs particularly in the vicinity of the ostia of the maxillary and the sphenoidal sinuses, owing to the loose nature of the reticulum in these regions is not substantiated in my own cases, nor does the cell arrangement about the ostium lend itself specially to swelling. This does not apply to the pedunculated polyps which frequently have their attachment near the ostium. Cell membranes in which edema has developed during the seventy-two hour period of observation, while they may present a lobulated appearance, are still more or less uniformly affected. If any portion of the sinus lining might be considered more susceptible than another, it would appear to be the floor. The reason for this is doubtful but may be attributable to the relative frequency and degree of irritation produced by exudates gravitating there.

A Possible Source of Chronicity. *One is increasingly impressed with the probability that the chronicity of many*

sinus infections depends not upon the failure of the body to throw off some old initial infection, but upon the daily reinfection with some strain of microörganisms or some virus, or even some fungus to which the subject is susceptible; and that these strains may be geographically regional in their distribution. That being the case, the patient harbors pus in his nose at intervals in spite of anything one can do. He continues for months and years in a state of mild upper respiratory infection —his "catarrh"—which indulges in occasional exacerbations, and never quite subsides. He leaves town for a few weeks—it matters little where he goes—the trouble disappears; not a trace of it remains; he returns home and in a week's time the old sinusitis is at its old level; and this is the significant thing: It does not recur as an acute cold which later stubbornly hangs on; but it sets in gradually and continues mild. *It is as though the patient were taking daily some noxious drug which was discontinued for a time and later resumed.*

Recent experiences with the allergic responses of many patients to certain bacteria indicate that specific sensitivity to these organisms may account for the condition.

Chronic Sinusitis. Much has recently been written regarding the probability of the regeneration of ciliated columnar epithelium in sinuses following complete exenteration, and there is little doubt that such regeneration does occur, but this appears to me to be only part of the issue. Undoubtedly the significant element in sinus disease, both as regards the general health of the individual and the local prognosis, is the deep infection of glands and subepithelial tissues. Chronic sinus disease is characterized by an increase of connective tissue, usually beginning in the vicinity of blood vessels, and even in the earlier stages the deep periosteal layers show thickenings and irregularities. According to Wright, the actual increase in the volume of the connective tissue is often more apparent than

real. The bulk of increase in the stroma is due not to proliferation of the connective tissue alone but to the dilatation of the lymph spaces and the filling of the meshes of the stroma with serum and corpuscular elements, lymphocytes and polynuclear cells. "This is apt to be specially well marked in the superficial or subepithelial layers, the deeper stroma alone showing increase in the fibrous connective tissue strands."[233] This is fortunate as these superficial layers by their accessibility are rendered amenable to treatment.

INDICATIONS FOR EXENTERATION. There is no fault to be found with radical exenteration of accessible sinuses provided that a normal mucosa, or at least an uninfected one, not merely one covered with ciliated columnar epithelium, takes its place. Unfortunately, in comparing sections of membrane originally removed with that which has replaced it, the same areas of inflammatory reaction, lymphocytes and polynuclear leucocytes are sometimes seen to recur. In advanced chronic sinusitis with hyperplastic membranes, it would appear logical to adopt surgical exenteration in those cases in which sub-epithelial infection occurred and in which a contraction of elastic tissue had advanced sufficiently to interfere with nutrition and prevent restoration of cells. Undoubtedly cases exist in which general sclerosis of the membrane is far advanced in which no active inflammatory process persists, symptomless and without harm. Any treatment of such a sinus merely on the basis of X-ray findings is pointless.

There is, however, a large proportion of sinus infections, comparatively recent and as yet not accompanied by pronounced deposits of connective tissue nor circulatory constriction, which can be eradicated by reducing the mass action of bacteria through the establishment of adequate drainage and ventilation, and at the same time stimulating the glands to discharge their infected contents.

This work does not concern itself with the problems of operative procedure, and the omitting of their discussion should not be construed as undervaluing them. There are, however, only two surgical objectives to be considered, and the decision to operate should be based entirely upon the likelihood of achieving them. The first is ventilation and drainage, which may be established by any sort of opening which can be maintained. If a cure can be effected by mere drainage, almost any permanent opening will suffice. Beyond this, however, it is difficult to see how the removal, however complete, of one or at most two walls of a six-sided rhomboidal cavity will greatly affect the situation. The second objective, complete exenteration, is then the only alternative, and even this must fall short of its goal if in the regeneration of the membrane the old infection regenerates along with it.

Our problem here is with the effects which may be produced by solutions acting on the mucosal surfaces to establish drainage or in some way to assist the mucosa in eradicating infection. As Wright indicates, the depositing of connective tissue is extremely slow, and there is a long period of dilatation of the lymph spaces with serum and inflammatory cellular elements before it takes place. During this stage much can be done toward the restoration of the tissues by means of astringents, vasoconstrictors, antiseptics and lubricants, without surgical intervention. The ostium is the Thermopylae of the situation. Here a minor swelling may so interfere with aeration and venous circulation as to maintain a diseased condition in the sinus which, if allowed to continue, eventuates in ineradicable changes Although some vascular and lymphatic circulations enter through the bony walls of the sinus independent of their ostia, still a venous blockade at this point may suffice to cause an edema which will effectively close the ostium. While there is some uncertainty regarding the exact nature of

the innervation of sinuses, undoubtedly pain impulses result from these blockades and probably vasomotor irregularities as well.

INFLUENCE OF FLUIDS ON OSTIA. While the location of the ostium in relation to its cell determines the amount of fluid which can be introduced into the sinus, its position has little influence on the treatment of the ostium itself; that is, small amounts of fluid are almost certain to pass in and out of the opening if it is at all patent, and these few drops are sufficient to react on the ostium. By the use of astringents, for instance, the opening may be so increased as to permit access to the sinus itself. The shape of the opening has some effect upon its penetrability. Ordinarily it is a simple round or oval orifice, opening into the sinus either at right angles or somewhat obliquely, but it may be surrounded by folds of membrane which constitute, in effect, semi-lunar valves when they become swollen. The resulting valve action is especially characteristic of the vasomotor type of rhinitis.

The simple reduction of edema at this tactical point by vasoconstrictors or astringents often succeeds in bringing about a return to normal. It is relatively difficult to infect intact nasal mucosa, but when once the epithelial barrier has been broken down the mass action of bacteria is a potent factor in the prognosis. Here mechanical washing with isotonic saline solutions may restore the injured tissues to a point where normal healing can take place. Whether for the time being it affects ciliary action or not is unimportant. Mild antiseptics are useful in reducing the mere mass of septic surface material, but little is to be expected from them within the tissues, where their penetration in effective concentrations is problematic. Effective antiseptics may yet be devised which are non-irritating to sinus walls after continued contact, but I know of none at present. The effectiveness of penicillin, locally applied, has been dis-

appointing. Certainly no antiseptic should be introduced in which there is any likelihood of decomposition or disintegration into irritating components at body temperatures in the course of a few days.

SOLVENTS AND DILUENTS. It frequently happens, especially in atrophic conditions, that an irritation is maintained by the retention and inspissation of secretions which under ordinary conditions would be relatively innocuous. Lubricants in the form of glycerin well diluted or of vegetable or mineral oils may relieve this condition, although it is not to be expected that they will cure it. In atrophic rhinitis, with ozena and crusting, oils introduced by displacement have proven moderately effective, but the best results have been obtained with the alcohol-glycerine-salt solution, the "A-G-S" drops described in the following chapter. Drugs, to be retained for any prolonged period in the sinuses, must be chosen with extreme care and employed sparingly to avoid irritation.

ASTRINGENTS AND VASOCONSTRICTORS. By far the most effective class of drugs for use by displacement are the vasoconstrictors. Inorganic astringents are seldom used in the nose nowadays, although mildly hypertonic saline solutions are effective in dehydrating the swollen surface elements of the mucosa. Continued use of hypertonic solutions is said to bring about metaplasia of the epithelium, including a destruction of the cilia. The media of choice in reducing surface swellings in all stages of inflammation are the vasoconstrictors, ephedrin and its salts, epinephrin and cocain. The two latter should not be introduced by displacement: first, because of the impossibility of removing them should symptoms of poisoning arise, and second, because of their immediate static effect upon the cilia. Numerous other vasoconstrictors are now on the market. From among them the author

has selected 2-amino-heptane-sulfate for routine use because of its persistent action and its freedom from systemic effects. Like most of the others, it does not damage cilia. In certain unexplained cases it is irritating and should be discarded in favor of ephedrine.

The success of treatment with any solution depends primarily upon the condition of the surface cells, their receptivity to the solution and the degree to which the pathologic process has progressed.

* * *

It is in the field of treatment that displacement has been of greatest service. That the introduction of treatment solution actually into the sinuses should be more effective than a mere nasal application is to be expected. The caution with which the method was first approached was prompted by the possibility that the various fluids remaining for several hours in contact with the mucosa might do it harm. This is not the case, as experience has shown, provided that the more irritating solutions are avoided.

In the management of headache, the apparent paradox has been encountered that the greatest ultimate relief is achieved in those patients who complain of headache after the first instillation. One can only surmise that this is due to the fact that the headaches occur in cases of relatively active inflammation in the sinuses or in those which have long been blocked, and which do not accept the solutions without pain. Old hyperplastic membranes, on the contrary, are inactive, not painful, and are less likely to yield to treatment. The severe headache following the initial displacement does not contraindicate a second two days later, which is commonly much less painful. Subsequent displacements are usually not followed by headache; in fact the headache disappears altogether.

A single irrigation often brings this about. (See page 69.) Shambaugh[19] says "a single irrigation has cured a sinus infection of years' duration. Usually a series of a dozen or more irrigations are necessary before the washing is negative, and the symptoms disappear. Even where the initial irrigation produces liquid pus with a foul odor, the chronic infection may be cleared up with irrigations alone, so that in every case of chronic purulent maxillary sinusitis, simple irrigations should be given a trial and chronic ethmoiditis sometimes responds to repeated evacuation by the displacement technique." This author also finds it of help in the diagnosis of ethmoid disease.

Extremely useful to me in the matter of prognosis is a simple procedure, which, for want of a better name, we call "washing through." Immediately after the completion of the displacement treatment, and before the patient moves, continuous suction is applied at one nostril while a syringeful of the treatment solution is poured into the other. The effect of this is simply to draw the nasal contents, with whatever may have washed out of the cells, into the glass container of the suction tube where they may be studied.

The back-and-forth movement of the fluid through the ostium of the inverted antrum is so effective in emptying it of pus that displacement can replace the cannula or the trochar in most cases.

When the contents appear in the glass tube as the result of the "washing through," the following changes are the rule:

After the first washing, the antrum contents are apt to be in the form of a single large opaque yellow lump, floating in the washing fluid.

After the second washing the lump gives place to a series of ropes, still yellow and still opaque when the tube is held up to the light.

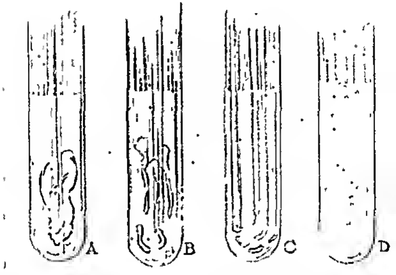

Fig. 32. Appearance of the secretions gathered in the tub after "washing through." A—First stage, solid opaque mass of exudate. B—Second stage, still opaque but in shreds. C—Thire stage, material scant and curded. D—Fluid clear, but heavily charged with mucus.

After the third or fourth washing, the material consists o few curds which settle to the bottom of the tube.

This is followed by what appears to be clean wash flu but what on closer inspection and upon slowly pouring it o proves to be clear, heavy mucus. (See Fig. 32.)

Treatment should not be suspended at this time, or rec rence will almost surely follow. It should be continued ur the thick masses of mucus no longer appear.

With these progressive changes in mind, it is my practice continue displacements every second day so long as impro ment is definite. If conditions do not advance from any sta to the next after a few displacements, the method is abandon for something more drastic.

CHAPTER VII

SOLUTIONS

LOTIONS AND DILUENTS — ANTISEPTICS — LUBRICANTS — VASOCONSTRICTORS — ANAESTHETICS — CONTRAST MEDIA — GASES.

The solutions suitable for introduction into sinuses may be classified as follows:

1. Simple lotions and diluents
2. Antiseptics
3. Lubricants
4. Vasoconstrictors
5. Anaesthetics
6. Contrast media (This may be either some fluid stained so as to render it easily visible in contrast to the mucosa or it may be some radiopaque substance for use in X-ray diagnosis.)
7. Gases.

(1) *Lotions and Diluents.* These solutions are intended for simple cleansing of the mucosa, to loosen inspissated secretions and to dilute others in order to render the sinus contents either less acrid or less viscous. The simplest of these and the one ordinarily employed is an isotonic or physiological salt solution. It has been said[17] that even this solution causes some edema of the epithelium but it must be negligible in ex-

(2) *Antiseptics* to be used by any such method as displacement, in which the solutions are likely to remain in the sinus for protracted periods, must be carefully chosen for their non-irritating and non-toxic qualities. It is desirable also to avoid solutions of unstable compounds which, in disintegrating, liberate toxic or irritating substances. Dilute solutions of the common silver colloids are generally employed. Argyrol is used in concentrations of one-half to ten per cent.

It is my experience that in intractable cases of sinus empyema, especially in children, a small amount of argyrol added to the solution turns the tide. As the infection is obviously not confined to the surface of the membrane, the effect of the drug is less likely to be due to any antiseptic properties which it may possess than to a gentle stimulation of the glands which are made to empty themselves. The immediate effect is an increase of the secretion, soon followed by a gradual diminution. It is preferable to use it only once or twice, after which the constrictor alone is resumed.

I have produced headaches with a one per cent solution of Neosilvol, and have abandoned its use on that account. Holmes[61] regularly employs the ten per cent strength. It is his experience that after the headaches disappear there is relief from the original symptoms. Glucose solutions have not yielded satisfactory results.

One enthusiast, impatient with the length of treatment required, resorted to a one-half per cent solution of mercurochrome. "This was followed by considerable reaction on the part of the mucous membrane, which was temporary and subsided within a few hours. There were severe headache which lasted about twenty-four hours and emesis for about eight or ten hours." One considers such treatment unduly energetic.

Sluder preferred dilute aqueous solutions of phenol to the silver salts and employed them exclusively.

Metaphen and Merthiolate have been tried, but in each case it was considered that the antiseptic action of the solution was insufficient to justify the pronounced irritation which it caused. As a general rule, a mucous membrane which responds to palliative treatment at all recovers with the establishment of ventilation and drainage without the use of antiseptics.

In my experience the sulfonamides, locally applied, have given only indifferent results. Looking critically at their effects it is difficult to verify some of the claims that have been made for them and one is forced to the conclusion that improvement is no better than is usually achieved by the vasoconstrictors with which manufacturers combine them.

When they were first tried in chronic maxillary sinusitis the sudden cessation of purulent secretion seemed almost miraculous, until it was discovered that instead of being suppressed these secretions were merely coagulated in a single larger lump, too bulky to make its way out of an ostium. This could be repeatedly demonstrated in a patient with an operative opening in the naso-maxillary wall. It was also shown that even so-called micro-crystals could form a mass resembling plaster paris, which remained for indefinite periods in the cavity.

In the light of these findings, apart from their minor therapeutic value, the sulfonamides are not recommended for introduction by displacement.

Sulman[103] reports satisfactory results from the use of a paredrine hydrobromide-sulfathiazole solution but adduces no evidence to indicate that the combination has any advantage over

the constrictor alone. Other reports, some of them enthusiastic, appeared shortly after the sulfonamides were first used, but later studies have all resulted in more guarded conclusions.

Whalen[223] writes, "The local use of sulfadiazine in the concentration of 2.5 per cent in aerosol was found to be without effect in controlling the progress of nasal sinus disease, either of the acute or of the chronic type. . . . The only successful made of chemotherapy for nasal sinus disease was found to be that of giving full doses of the sulfonamide compounds by mouth."

Solutions of penicillin (sodium salt) in the concentrations recommended for topical application have no damaging effect on the cilia or the epithelium of the respiratory mucosa over periods useful in clinical practice.

Solutions of higher concentration tend to impede ciliary action in various degrees.

Preliminary to an investigation of the effects of penicillin on sinus infections, strips of ciliated respiratory epithelium were subjected to the drug in various concentrations[174] with the following results:

Periods for which the ciliary beat persisted during immersion were:

250 units per cc.	—25 hr. 50 min. to 27 hr. 45 min.
500 units per cc.	—15 hr. 25 min. to 19 hr. 35 min.
5000 units per cc.	— 3 hr. 20 min. to 6 hr. 25 min.
All controls	—27 hr. 35 min. to 28 hr. 20 min.

The tests with penicillin indicate that solutions in the strength recommended for local application (250 units per cc. isotonic NaCl solution) have no appreciable adverse effect on respiratory ciliated epithelium. The ciliary beat ceased only when the

epithelium disintegrated, which it did after some 27 hours. This occurred at approximately the same time in the controls.

In solutions of 500 units per cc. the active period was somewhat shortened (average 18 hours) and the beat was less vigorous throughout.

In solutions of 5000 units per cc. the beat was reduced to approximately half-speed within a few minutes of immersion and continued so, without further retardation, until it stopped completely in 3½ to 6½ hours, without any sign of surface disintegration. While this concentration has not been recommended for topical application it is useful to know that the stronger solutions are less well tolerated than the weaker ones.

Woodward[231] reporting on a large series of carefully controlled observations finds the local effects of penicillin in the nose to be very slight and the results of local therapy on the whole disappointing. My own experience is less extensive than Woodward's but it bears out his judgment and I have abandoned it for use in displacement. It is possible that other antibiotics may be found more suitable to the purpose.

(3) *Lubricants.* The effectiveness of lubricants in relieving sinus irritation and its attendant headaches was brought to my attention by Granger,[71] who described a case in which there was continuous headache day and night for four weeks, and which disappeared promptly and completely following an injection of lipiodol for diagnosis. Potts[164] cites the case of a woman with a headache of several weeks' duration who was similarly relieved. I have since encountered many instances of this nature and attribute the relief to the lubricating properties of the lipiodol rather than to any intrinsic therapeutic action of this oil (which is inert, at least with respect to its iodin content), because like results have followed the administration

of simple liquid petrolatum of low specific gravity. It is not unlikely that the headaches in these instances were due to the inspissation and possibly the contraction of the secretions in sensitive locations, or to the drying of the membrane itself through unequal ventilation, and that the oil relieved them by simple lubrication. The relief obtained can usually be obtained with aqueous solutions as well, without the potential danger to the lung.

(4) *Vasoconstrictors.* The best results to date from all standpoints have followed the instillation of 2-amino-heptane-sulfate .25%, in physiological salt solution. It is practically without discomfort, either immediate or deferred. Its action is slow but protracted; it remains effective for many hours and does not cause restlessness and insomnia. Ingestion of 25 mg. produced no demonstrable effect.[59] Strong solutions are unnecessary to effect the desired contraction. This agent effectively opens the meatuses and the ostia, and its gradual evacuation from the sinus maintains n free passage over a prolonged period, from twelve to twenty-four hours. It is customary to repeat the treatment on alternate days and thus artificially to maintain a condition approximating the normal, until the mucosa has had an opportunity to right itself and rid itself of the infection. The vicious circle of irritation, swelling and retention is in many cases the determining factor in the failure of the sinus to throw off infection, and the prolonged gentle constriction interrupting the cycle permits recovery.

For this reason and for a still better one, cocain must not be used for displacement. Not only is the local cocain reaction undesirable, but the solution, once instilled, is beyond control and in the event of toxic symptoms cannot be removed. No toxic effects have been reported following the use of ephedrine or 2-amino-heptane.

(5) *Anaesthetics.* Theoretically, mild topical anaesthetics introduced into the sinuses should relieve headache traceable directly to intrasinous involvement.

No drug satisfactory for this purpose has made its appearance. Cocain is dangerous and should not be employed for the reasons mentioned.

(6) *Contrast Media.* Aside from the radiopaques, which will be described in the following chapter, one visual contrast medium has been employed. This is oil of sesame or some other bland oil stained with a very small quantity of fat-soluble chlorophyll (Merck). The dark green color of this mixture is in contrast to the reds and yellows of the mucosa, and can be traced by inspection. Even when the amount is so small as to be invisible in the nose, it can still be detected in the secretions against the white background of the patient's handkerchief. This is a very inaccurate diagnostic procedure and is not recommended.

(7) *Gases.* With the advent of effective vasoconstrictors in gaseous form, a method seemed desirable for introducing these also into the sinuses. Inhalers, even those of today which are vastly superior to the earlier ones, have one shortcoming in common with the atomizer, namely, that the drug does not penetrate the ostia, especially those blocked with secretions.

A simple means has been suggested for applying the Displacement principle to gases.[173]

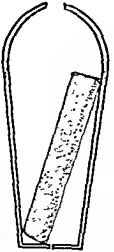

Fig. 33.

The appliance consists simply of a bomb-shaped container, similar to those now used for most inhalers and carrying the familiar cotton cylinder saturated with the volatile drug. A *small* hole is drilled in each end of the container. (Fig. 33.)

Using the same pumps, the same pressure and the same olive tip as for displacement with fluids, intermittent suction is applied to one nostril while the patient keeps the mouth open and the velum palati in the "k" position. Naturally no fluid is introduced.

Now, instead of closing the opposite nostril with the finger, the perforated olive tip of the container is inserted snugly into it. (Fig. 34.) The negative pressure draws the fumes into the nose from the container and, at the same time, evacuates part of the air from the sinuses. With its release small quantities of vapor-laden air are carried into the sinuses. The pressure is applied a number of times as in displacement with fluids.

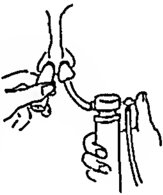

Fig 34

It is absolutely essential that the small hole of the distal end of the container be not larger (and it may be smaller) than 1/64 inch in diameter—in other words a pin hole. If this *hole is any larger, then it becomes impossible to attain the necessary negative pressure in the nose to exhaust air from the sinuses.*

The hole in the proximal olive-tipped end which is inserted in the nose may be of any convenient size but should be somewhat larger than 1/64 inch. Experiments with a model show that if this hole is too small, the vapor enters the nasal chamber in an undesirable jet rather than in an evenly distributed stream.

It is axiomatic that the cleaner the nose the more effective the penetration will be. Therefore, in most cases it is advisable not only to shrink the nose but to cleanse the meatuses as far as possible with a thin suction tube.

It may, at first glance, seem immaterial whether the alterations in negative pressure be made from the side of the suction tip or through the container. However, the latter practice is not effective, since the release of pressure through the pin hole is too gradual to allow complete equalization.

One should exercise some caution in the choice of a volatile constrictor which is liberally used and which may be retained for a time in the sinuses. Our own experiments have been made with a preparation of 2-amino-heptane which has been shown to exhibit a minimal systemic effect.[28, 173]

While gases are less effective than fluids, they have this advantage: that they do not spread the infection and may be used in the acute stages of the attack.

This maneuver is somewhat reminiscent of an experiment described by Coffin (p. 4). History in repeating itself usually adds a few embellishments. In this case one might regard as an embellishment the volatile constrictors which did not exist in Coffin's day, were it not that here they constitute the cardinal factor in effectiveness.

It will be unnecessary to add that since gravity does not play a part, the usual position is dispensed with and the patient kept in the erect position.

CHAPTER VIII

RADIOPAQUES*

HISTORICAL NOTES—LIPIODOL—BROMINOL — IODIPIN—BROMIPIN — LIPOIODINE — CHARACTERISTICS OF HALOGENATED OILS.

The difficulty of clearly defining the delicate overlapping outlines of the nasal sinuses roentgenographically has tendered the use of opaque substances in this region desirable. The earliest experiments with radiopaques were unsatisfactory. Various pastes, emulsions and suspensions of metallic salts were employed, which were given to caking, and led to serious difficulties in removing them after the examination. Before 1922, when halogenated oils were introduced, only sporadic references were encountered in the literature. In no case do we find the subject further pursued by its author, from which it may be deduced that even he soon found his method impractical.

HISTORICAL NOTES. Fraser[4] credits Moritz Weil[71] with the first injection of a contrast medium into a paranasal cavity. His studies, confined to the maxillary and frontal sinuses, were made in 1902-03; aqueous mixtures of lead sulphate were used. They were introduced by means of cannulæ through the

*"Radiopaques"—There is need of a simple substantive to designate these opaque materials as a class. The awkwardness of such phrases as "contrast media," "radiopaque substances," "halogenated oils" and the like has frequently led to the use of some proprietary name as a generic term. The adjective "radiopaque" is commonly accepted, and appears in Dorland's American Medical Dictionary. Webster permits the use of "opaque" as a noun as well as an adjective. Based on this authority, the substantive "radiopaque" is suggested as a convenient and explicit generic term.

DR. MORITZ WEIL, OF VIENNA, WHO WAS THE FIRST TO EXPERIMENT WITH RADIOPAQUES IN THE SINUSES, AND A PRINT OF HIS FIRST PLATE.

ostia with the patient lying in a prone position to facilitate filling.

Following Weil's example, Beck and Ramdohr[11] and others (Feuchtinger,[11] Tschiassny[219]) injected suspensions of bismuth or some of the heavy metals in aqueous or oily mixtures; barium sulphate and various solutions of potassium iodid were unsuccessfully employed (Brunetti and Filippini[21]). These substances proved unsatisfactory because of the difficulty of introducing and removing them and also because of their osmotic peculiarities and irritative tendencies.

The accidental discovery, in 1922, by Forestier and Sicard[70] that the fixed halogen compounds of certain oils were inert and radiopaque, and could be injected into the various body cavities without danger has resulted in refinements of sinus diagnosis which were previously impossible. Although much of the pioneer work with lipiodol was done by these Frenchmen, they were not the first to apply it to sinus diagnosis. It was not until 1925 that Reverchon and Worms[176] injected the oil into the maxillary sinus and thus achieved the first practical sinus diagnosis by means of radiopaques. In the same year, Dobranski and Lanartowski[40] confirmed their results, and Proetz[174] introduced the Displacement Method of injection. In the following year appeared a number of clinical reports confirming the successful application of fluid radiopaques to sinuses. (Fraser,[64, 53] MacCready,[126] and Goodyear,[91] in this country, and Blondeau,[18] in France.) Later publications have dealt chiefly with the diagnosis of specific conditions and with refinements in head *positions* and angulations for radiography. Some authors prefer one mode of administration and some another. In my own opinion, this should be determined by the requirements and the difficulties of the individual case, factors which will be considered elsewhere.

Since the success of lipiodol, other halogenated oils have made their appearance. All of these are closely related in their chemical nature and are fixed iodin or bromin compounds of some bland vegetable oils or their esters. They vary chiefly in their viscosities, their density to X-rays, their stability and the degree of irritation which they produce in the tissues. In sinus work, it is of first importance that the fluid be non-irritating and that its viscosity be relatively low. Conditions in the accessory sinuses are unlike those encountered in the bronchi in that the fluid, instead of spreading into thin coating films, remains in relatively large masses; therefore high viscosity is unnecessary and may hamper introduction and elimination. For the same reason extreme radiopacity (that is, high halogen content) is likewise unnecessary, and many of the oils may be diluted as much as four or five times to advantage.

For the following brief descriptions of the better known oils the physical and chemical data have been supplied by the manufacturers; the recommendations as to their individual adaptability to sinus work are the author's.

Lipiodol (Lafay) is a fixed compound of iodin with poppy-seed oil, containing 40% iodin by weight. It is in no sense a solution or mixture. The iodin enters into the molecule of the combination. It is stable to acids and can be boiled with concentrated nitric acid without liberating iodin. It is an amber colored oil, of a slightly pungent odor and faintly brackish taste. At ordinary temperatures it is quite viscous, becoming much less so at temperatures ranging from 35° to 40° centigrade. It has a density of 1.35.

"Since lipiodol is slightly altered under the influence of light, air and high temperature or humidity, it sometimes becomes slightly brownish in color, due to the liberation of small quantities of iodin, which dissolve in the oil. It is very important

to note this color and to avoid injection of lipiodol thus altered. This small amount of free iodin may produce severe irritations and prove dangerous if the injection should be made into so delicate a cavity as the subarachnoid space."[101]

For use by displacement, it is recommended that this oil be diluted with one to three parts of olive oil.

Brominol (Abbott) is supplied in two types, heavy and light. Brominol Heavy has the high viscosity required for bronchial work. It does not meet the requirements of the Displacement Method. Brominol Light is ideally suited to the method. It has a low viscosity and a pleasant aromatic odor, which is of some consequence considering that the patient may be conscious of its presence for several days. In conformity with the usual terminology applied to oils, the low viscosity 33 per cent brominized olive esters is known as "Brominol Light." When high viscosity is of advantage, a mixture of 85 per cent brominized olive oil and 15 per cent brominized olive esters, designated as "Brominol Heavy," is used. This has a viscosity almost identical with that of the other heavy halogenated oils.

Particular attention is called to the fact that by mixing the above described oils in suitable proportions, any desired intermediate viscosity may be secured by the radiologist without a sacrifice of radiopacity, the bromin content remaining 33 per cent.

When injected into the pericardial and pleural cavities and allowed to remain for some days, brominized olive oil is said to be far less irritating than any of the iodized oils now available. It has been further established that rabbits tolerate amounts of these oils equivalent to 2 grams of bromin per kg. of body weight, when given orally. This is almost twice the tolerated dose of typical iodized oil.

This is a highly satisfactory radiopaque for displacement. However, it should be obtained fresh. If used after it has darkened to a brown color, headaches follow.

Iodipin (Merck) is a 40% combination of iodin with the fatty acids of "selected vegetable oils." It is a yellowish brown oil, having a specific gravity of 1.35 and containing 0.54 grams of combined iodin per millilitre.

Bromipin 33% (Merck) is a straw colored brominized oil of sesame. As in the case with the other halogenated oils, the bromin is held in chemical combination with the fatty acids of the oil. At 15° C. it has a specific gravity of 1.30. The oil should be warmed to body temperature for administration.

Lipoiodine (Ciba) is the ethyl ester of di-iodobrassidic acid containing about 41% iodin. *Lipoiodine Diagnostic* is a 60% solution of Lipoiodine in sesame oil. The viscosity of this preparation is fairly low, and, since its iodin content is only about 24%, its opacity is also relatively low.

Some of the heavy oils on the market intended for bronchography and other purposes are unsuitable for displacement unless they are considerably thinned. It should be borne in mind that emptying time will be altered if oils of higher or lower viscosity than those specified are used.

CHARACTERISTICS OF HALOGENATED OILS. The following excerpts are from "A Study of the Halogenated Oils Employed in Roentgenology" (Tabern, Hansen, Volwiler and Crandall[290]). "*In addition to those iodized oils commercially available, certain other typical oils were synthesized. These were prepared either by the direct action of iodin in the presence of mercuric chloride or by the action of iodin monochloride in aqueous solution.*

"From a chemical standpoint, the most suitable products for roentgenographic use were secured when the parent oils were

of vegetable rather than of animal origin. A group of brominized lard oils containing from 10 to 32 per cent of halogen were studied in detail; in addition to a tendency toward rancidity, the continuous formation of a flocculent precipitate offered serious objections to their use. Cod liver oil underwent extensive decomposition during bromination.

"Among the so-called vegetable oils, olive oil was found to possess many advantages. It is relatively constant in composition and readily purified. It is almost entirely free from glycerides having more than a single double bond. A suitably prepared 33 per cent brominized olive oil may be heated to 120° for several hours without appreciable decomposition. Exposed to air and sunlight in the laboratory, it is not only perfectly stable but even becomes lighter in color. The same valuable features are characteristic of the corresponding ethyl esters and their bromin derivatives.

"The esters of the oils are much less viscous than the oils themselves, and the same is true of the corresponding halogenated products. Expressed in terms of viscosity in seconds (with water taken as 1 second) 44 per cent brominized olive oil has a value of 170 sec., while the corresponding ester is only 7. sec. It is to be emphasized that inasmuch as the halogen content is the same in each, their radiopacities are identical. . . . as the brominized oils and esters are miscible, by their simple mixture in predetermined proportions, an oil of any intermediate viscosity most suitable for the case at hand may be easily secured.

"Another suggestive point is that the brominized olive esters approximate very closely the viscosity of the body fluids. Thus, pharmacologic experiments, such as the delineation of mobile areas and of the circulatory system, take on a new degree of accuracy, and entirely new fields of study are opened up.

"The stability of their halogen when in contact with aqueous media, suggests the value of the brominized olive oils and esters in the preparation of permanent radiopaque emulsions completely miscible with water.

"Crandall and Walsh[31] observed that contrary to popular supposition, lipiodol and iodopin, when injected intrapericardially and intrapleurally, produce marked irritation. Subsequent experiments demonstrated that under the same conditions brominized olive oil is almost *entirely non-irritant.* The question then arose, of course, whether the property of producing irritation resides primarily in the oil or the halogen portion of the molecule. . . . The irritation produced would seem to be independent of the degree of unsaturation, since both olive and linseed oils, particularly the former, are almost entirely non-irritating.

"In general, the esters are somewhat more irritating than the oils, although the ethyl esters of lard and corn oils appear to be exceptions to the rule. Ethyl brassidate proved markedly irritating. In the group of homologous esters, the methyl and ethyl are roughly equivalent, while the butyl and octyl derivatives are quite inert. In the same way, butyl stearate is less irritant than ethyl stearate, and benzyl oleate appears better than butyl oleate.

"To test the effect of the presence of pure fatty acids, varying percentages of pure stearic and oleic acids were added to olive oil. It was found that 0.5 per cent of stearic acid produced as much irritation as 5 per cent oleic.

"The effect upon the esters of distillation at 10 mm. or less was tested. The distilled products proved superior, while the residue in the distillation flask was strongly irritating.

"While castor oil produced no ill effects, the ethyl esters of this oil caused death without great irritation. This may well have been due to the rapid absorption of the ricinoleates present in the esters."

CHAPTER IX

METHODS OF INTRODUCTION AND THE ADVANTAGES OF EACH

CANNULIZATION—PUNCTURE—DISPLACEMENT.

Most of the clinical reports encountered in the literature are confined to the easily accessible antrum and only occasionally to the relatively accessible sphenoid. The ethmoids are carefully avoided; it has even been maintained that they cannot be filled![219] The accompanying roentgenogram, and others here reproduced, illustrate the fallacy of this contention. The ethmoidal cells are not only adequately filled, but in this case the oil shadows clearly outline a hyperplastic membrane. (Fig. 35.)

CANNULIZATION. Sinuses whose ostia are readily accessible, and of sufficient size to permit the introduction of a cannula, are most simply filled by this means. Where so simple a maneuver attains the desired end, it were folly to employ any other. Unfortunately ostia are rarely so accessible as to permit the insertion of cannulæ without any trauma, and without local anaesthetics or astringents, conditions which are necessary for the satisfactory study of normal drainage. Sphenoidal and maxillary sinuses are comparatively easy of access, the frontal cells are much more difficult and the ethmoidal practically impossible, because of the situation of their ostia and their complicated structures.

The cannula should be of such size that no trauma occurs and that air may freely escape around it. It should be curved, with the curve almost a right-angled one and with the tip short enough to be easily turned under the middle turbinate

Fig. 35. Generalized filling. Thickened membranes are clearly demonstrated in both anterior and posterior ethmoid groups.

and to fall short of impaction against the opposite wall. To minimize this accident, it should have one or two auxiliary lateral openings near the tip. If extensive filling is desired, the fluid is simply injected until it overflows into the nose, care being taken to place the head so as to bring the ostium of the sinus near the top. To insure maximum filling in the case of the sphenoid, the patient is laid flat on his back; in the case of the antrum his head is tilted toward the injected side.

In most cases the frontal sinus, when at all accessible, can be most easily filled by means of a cannula. Some shrinking and cocainization are almost always necessary, and the trauma

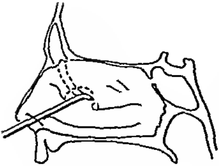

Fig. 36. Cannula in the normal maxillary ostium.

may be lessened by preliminary exploration with a thin, soft probe. The cannula is then reshaped to correspond to the curve of this probe, and the injection is made with the patient lying on the side to be injected.

Filling the ethmoidal cells by cannula is impractical. If their ostia can by some accident be found, only the immediately neighboring cells receive any of the fluid and in amounts insufficient for diagnosis.

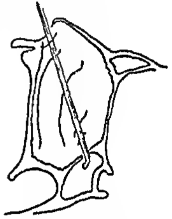

Fig. 37 Cannula in the sphenoidal ostium.

In difficult cases the fluoroscope may be employed to advantage in directing the cannula, even though the fluids employed are not radiopaques.

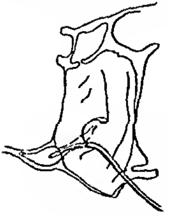

Fig. 38. Cannula in the frontal sinus.

The advantages of cannulization, in situations to which it is adapted, are its extreme simplicity and the degree to which the amount of filling can be controlled. It has the disadvantage of filling only a single cell and of being feasible only where the ostium is easily accessible.

PUNCTURE. In sphenoidal and maxillary sinuses which are accessible, although their ostia are not, filling may be accomplished by puncture through the bony wall with a trocar. In the case of the antrum, this is sometimes to be recommended on account of the accessibility of the thin *processus maxillaris* of the inferior turbinate and the relative freedom from danger. In the sphenoid it is seldom the method of choice, inasmuch as this cavity can be more satisfactorily filled by displacement. It is therefore recommended only in sphenoids in which, having already been shown by their failure to fill by displacement to be diseased, one still desires for some reason to obtain a filling. It is not to be thought of in frontal or ethmoidal sinuses.

The advantage of filling by puncture is again its readiness of accomplishment and the ease with which the amount of fluid ean be controlled. It produces trauma which is, in most cases, unjustifiable, especially where drainage time is to be estimated. While I believe the dangers of antrum puncture have often been overstated and have in some measure been due to faulty technic, it is unnecessarily brutal, especially when it becomes necessary to repeat it often.

DISPLACEMENT. Displacement has its advantages and disadvantages. It is particularly suitable to the filling of the posterior series of sinuses and is here to be preferred, with rare exceptions, to other methods. While the anterior ethmoids permit a scattered filling and do not present the characteristic dense outlines of the other cells, they are by nature small and scattered, and are incapable of filling by any of the other methods. The extent to which the antrum may be filled by displacement depends entirely upon the relation of the ostium to the cell in the position of filling. When a single antrum and no other cell is to be filled, the author does not resort to dis-

placement but employs cannulization. However, in the general filling, with the head in the exaggerated supine position, sufficient oil ordinarily penetrates the antra for complete diagnosis. That is, the fluid is found normally to a depth of 0.5 cm. or more, which is sufficient to determine the thickness of the membrane, the nature of its surface and the presence of polyposis. Exposed in the vertical position, it delineates the alveolar relations of the antrum and irregularities of the floor. It is sufficient also for the estimation of emptying time; in short, it accomplishes all that the more extensive fillings do.

The frontal sinus is the most difficult to fill by displacement. Owing to its long and tortuous hiatus, air bubbles are not readily displaced from this sinus. In case of necessity, however, fluid may be introduced in the prone position or in the exaggerated supine position of Fraser, but it is recommended that in this case the tissues of the middle meatus be thoroughly shrunken. If the solution is an astringent introduced for treatment, a very small amount will sometimes suffice, as in the erect position it remains in contact with the dependent portion of the sinus and its outlet, where its action is desired. In the case of radiopaques, small amounts suffice, as films are made routinely in three positions.

This is also true of the antrum.

Displacement has three distinct advantages over other methods of filling. The first is that, since it depends upon gravity, the fluids themselves seek out and enter cells, no matter where they lie. It is often a remote cell or one unusually placed which is the center of trouble and which is never discovered by other methods. Second, it accomplishes its filling without contact of instruments, and hence without trauma. Third, it results in a general filling which is necessary for the estimation of relative drainage time.

It can be resorted to frequently for treatment and can be continued, if progress justifies, over a long period of time without damage or discomfort.

It sometimes happens that even with the blandest fluids headache follows the first introduction, but this is transient and seldom recurs after subsequent injections. Whether this is due to the action of the fluid upon old inspissated exudates in the sinuses or to some other cause is problematical. It is suggestive, however, that as soon as these secretions are freed, headaches cease. (cf. discussion of headache, p. 65.)

I once feared on theory that some harm might come from the application of suction to the nose in the inverted position to old people or to those suffering from high blood pressure. Such an accident has never occurred in my own experience nor in any case coming to my attention.

It was feared also that solutions might enter the eustachian tube and the middle ear and give rise to irritations or infections there. This likewise has not occurred, owing to the length and nature of the eustachian tube and the small air chambers at its extremity, which preclude the possibility of extracting air and therefore prevent access of fluid. I have attempted to fill the eustachian tube for demonstration but have failed.

It occurred to me at the beginning that there might be danger of carrying infected fluids into sterile sinuses during treatment and for that reason I have never employed displacement during the vascular stage of acute inflammation. I do not know of a single instance in which infection has been spread, which I can explain only upon the ground that by the time displacement was employed, the individual's immunity had progressed so that bacterial growth did not occur in the

presence of the solutions employed. The fact remains that new infections have not occurred

Some time ago there were vague reports that during a displacement for the introduction of a radiopaque, the oil had escaped through a dehiscence in the cribriform plate and that subsequent radiographs showed it in the spinal canal! This is patently impossible, since no air could be displaced through such a dehiscence, there being none to displace. Investigation revealed that in this case the oil had been *injected with a syringe* by an inexperienced person, who was under the impression that it was entering the sphenoidal cavity.

CHAPTER X

ROENTGENOLOGY

GENERAL CONSIDERATIONS — EXPOSURE DATA—TUBES — BUCKY DIAPHRAGM — PRECISION APPARATUS — ERNST'S—BAUM'S — ISRAEL'S — HORIZONTAL BEAM—ROUTINE VIEWS.

Ordinarily the introduction of radiopaques is not performed on the radiologist's table. Unless some special circumstance intervenes which makes it undesirable to permit the patient to assume the erect position between the introduction and the radiographic examination, such as, for instance, an extreme degree of atrophy or some operative opening which allows the oil to escape, the instillation is done in the laryngologist's office and the patient walks to the radiologist's. This is the routine practice, provided that the radiologist is so situated that not more than fifteen or twenty minutes need elapse between filling and exposure. Conditions which allow the oil to escape at once are usually obvious, and do not require radiography.

While the general radiological practices in regard to tube distance, current and exposure apply also with radiopaques, special precautions in regard to the position of the subject and the relative positions of tube, head and film are indicated, the non-observance of which spells inaccuracy and failure. The pool of oil in the sinus naturally gravitates to the bottom and its shadow varies enormously with slight alterations of position. (See Fig. 100.)

Partial fillings are easily mistaken for thickened membranes and irregularities of contour occasioned by small septa or other anatomical structures may be misinterpreted as pathological changes. Ignorance of, or indifference to, these few precautions

is at the bottom of most of the failures in diagnosis with opaque injection.

Whatever angles the individual observer may have adopted can be retained with radiopaques, provided these angles are translated into one of the horizontal beam positions as described below. Once the angles of choice have been established, they should be rigidly adhered to in every case. It is only through familiarity won with experience that minor deviations from the normal are detected. Generally speaking, it may be said that most of the complicated angulations otherwise adopted to avoid the confusion occasioned by overlapping shadows are unnecessary with radiopaques, because of the sharp contrasts. One's own operating conditions and apparatus constitute individual problems which cannot be solved by any single formula of procedure.

EXPOSURE DATA. The following data have been supplied by Dr. Edwin C. Ernst to meet the conditions commonly encountered. Most of the illustrations in this book were made from Dr. Ernst's negatives.

Variable Factors

	Potential	*Exposure Time*
Postero-anterior base-line position	70 kilovolts	2 seconds
Lateral position	60 kilovolts	1½ seconds
Submento-vertex position	70 kilovolts	4½ seconds

Constant Factors

Tube anode film distance	31 inches
X-ray tube current	20 milliamperes

TUBES. In order to obtain roentgenograms of the highest degree of excellence it is essential to employ an X-ray tube having a very fine focal spot. Otherwise the desirable maximum soft tissue detail of the sinus walls will be sacrificed and scattered radiation increased.

The 1.5 K.W. or 2.5 K.W. line-focus tube is routinely used at a focal skin distance of 32 inches. It is important to attach a long metallic or lead glass cone (approximately 15 inches in length) to the tube holder, whose distal diameter measures 3 inches. These specifications are essential for obtaining the maximum degree of bone detail, so desirable in sinus radiography. The actual diameter of the exposure on the film is 4½ inches, which is sufficiently large to include all of the sinuses.

The resulting radiogram should then show few secondary shadows beyond the circle of the cone on the film, a condition indicative of the ideal X-ray negative for sinus diagnosis.

BUCKY DIAPHRAGM. If this method and the mechanical factors described are employed as part of the radiographic technic, the use of the Bucky diaphragm is, in our opinion, an unnecessary procedure. In making skull studies on films larger than 4½ inches the use of the Bucky diaphragm is distinctly indicated.

PRECISION APPARATUS. The selection of the method and the choice of apparatus for sinus examinations should be relatively simple and flexible from the radiographic viewpoint. It must be possible to immobilize the head completely under the most trying circumstances. The comfort of the patient must at all times be given due consideration, otherwise his full coöperation, so very desirable, cannot be obtained.

A special sinus apparatus has been devised by Ernst for this type of examination. The patient is placed in a swivel chair having a short back-rest with a 15° backward tilt. This chair is placed on steel tracks so that the patient's position in relation to the intensifying screen is uniformly maintained for all exposures. The 8 x 10 casette or screen film holder can be adjusted to the exact height of the patient's head in relation to

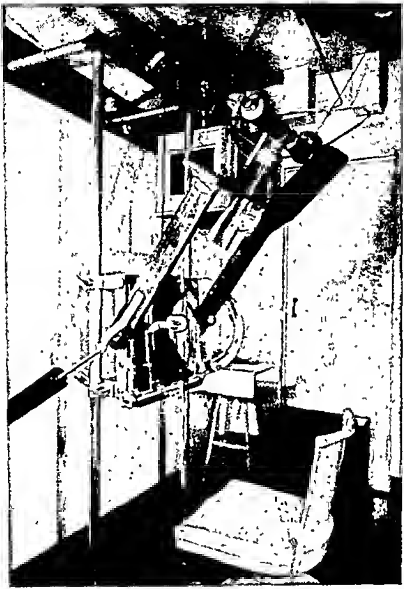

Fig. 39. Ernst's Precision Apparatus. The X-ray tube pivots *about the center of the film, keeping the central beam always directed* to this point and fixing the focal distance.

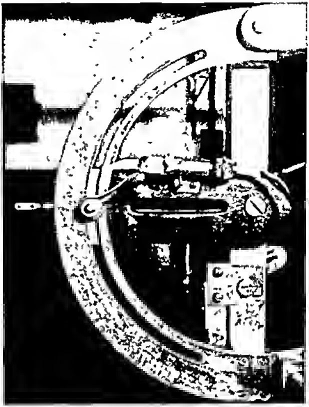

Fig. 40 Ernst's apparatus, detail to show the arc for accurate angulation and the small electric light which casts a shadow on the patient's face to indicate the direction of the central beam. The observation is made through the slot in the wooden arm.

the X-ray film and the X-ray beam. Both adjustments are accomplished by a single movement. The film holder is designed to hold 5 x 7, 8 x 10, or 10 x 12 casettes. Two sinus exposures or stereoscopic studies may with suitable blocking be obtained on a single 8 x 10 film.

The X-ray tube is attached to two cross-arms centered along the outer margins of the casette holder. The one cross-arm has a ¼-inch slit, opposite which is mounted a small incandes-

Fig. 41. Ernst's apparatus set for exposure of the postero-anterior base-line "Position 1," showing how the casette holder may be tilted backward and toward the patient to permit any relation of film and head to the tube without varying the beam from the horizontal.

cent light. The X-ray beam parallels the cross-arm so that the base line can be approximated by the shadow of the light falling upon the side of the face. (Fig. 40.) Thus an accurate direction of the central X-ray beam in relation to the base line is readily obtained from which all angles are routinely calculated and designated in our studies. The large semi-circular scale permits the direct reading of this angle.

In addition to raising and lowering the casette holder, it is also possible to tilt the lower end forward a maximum of 17° without changing the relations of X-ray beam, tube and carriage to this film holder. (Fig. 41.) This feature facilitates the maintaining of the X-ray beam parallel to the surface level of the radiopaque while the head is maintained at the desired angle above or below the beam. It is especially advantageous when the X-ray heam is below the base line.

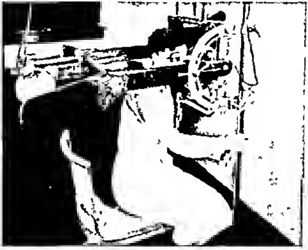

Fig. 42. Ernst's apparatus set for the lateral "Position 2."

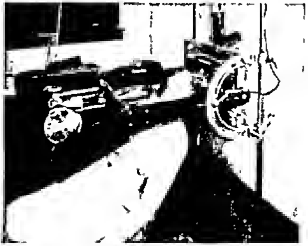

Fig. 43. Ernst's apparatus set for the vertical "Position 3." The lateral fixation of the patient's head is accomplished by means of the two pads, the occiput resting in the headrest shown in Fig. 44.

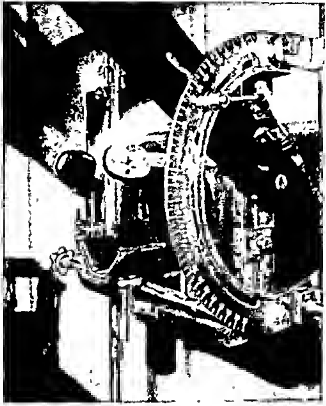

Fig. 44. Ernst's apparatus showing the headrests which are simultaneously moved to center the head.

The immobilization and centering of the patient's head are accomplished at once, since both lateral pads operate on a single worm gear. There is also a central pad for resting the occiput when the patient's head is placed face-up in position for the submento-vertical (ground plan) studies. (Fig. 44.)

Baum[9] has adopted a very simple arrangement of apparatus which permits making of exposures in either the erect or the horizontal position. (Fig. 45.) The tube distance and the angles are accurately determined. The central beam is not automatically centered upon the casette. Baum's work with this apparatus is of outstanding quality.

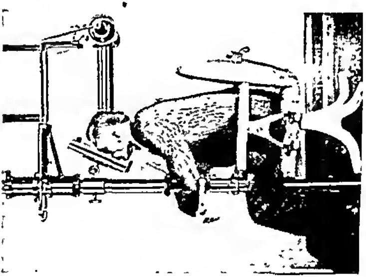

Fig 45

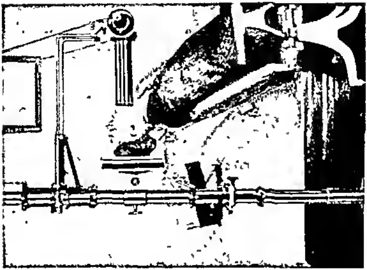

Fig 46

Baum's apparatus. Arrangement for a postero-anterior position, and for a "ground plan" view. The illustration on the right shows the adjustable shelf for the Granger sinus board with the vertical ray.

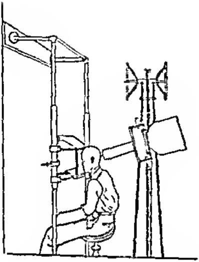

Fig. 47. Israel's apparatus. Schema showing central focus of the ray through nasofrontal articulation in upright position; nose and forehead on casette.

Israel[93] employs a stationary frame upon which the casette moves and by which the head can be immobilized in any position. (Fig. 47.) The tube stand, however, is not part of the apparatus, and therefore the beam bears no fixed relation to the film and must be adjusted for angle and distance at each sitting.

Allen[2] has demonstrated that with proper care adequately accurate angulation may be obtained without the use of any special apparatus. (Fig. 48 A, B and C.)

Horizontal Beam. Experienced observers have abandoned the vertical and nearly vertical beams and the horizontal position of the patient and film in favor of the horizontal beam passing as nearly as possible through the plane of the surface level of the radiopaque fluid, the film naturally at the same time becoming vertical. This involves no change in the angulation of the old familiar positions but is accomplished very simply by rotating the entire film-head-tube system through an arc of 90° without in any way altering their relations to one another. In the new position the sinus containing fluid is viewed from the side as fluids in test tubes or other containers are naturally examined. Gravity, holding the fluid to the bottom, comes to one's assistance, as explained in the following chapter.

It should be categorically stated that accurate localization of any kind, astronomical, geographical or roentgenological,

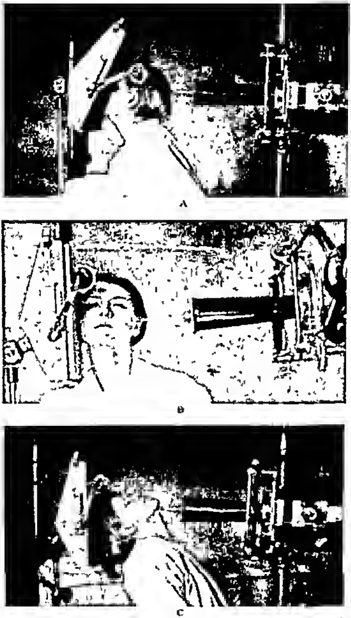

Fig 48 Allen's simple expedient of fixing a Granger sinus board in the vertical position He uses no special apparatus but centers the beam by means of the small brass contrivance seen between the head and the end of the cone, which is of course removed when the exposure is made

Fig. 49. Radiogram obtained in routine postero-anterior "Position I."

Fig. 50. Radiogram obtained in routine lateral "Position 2."

Fig. 51 Radiogram obtained in routine vertical (ground plan) "Position 3"

requires at least two views—that is, two observation points, from different angles. In sinus work three views are preferable. Only the most obvious shadows can be identified by means of the monocular vision afforded by a single exposure, and no experienced diagnostician would consider drawing conclusions from it.

ROUTINE VIEWS. Dr. Ernst and the author routinely employ three simple but very accurately adjusted positions. The first, a postero-anterior view; here the base line drawn from the naso-frontal suture to the external auditory meatus is horizontal, the central X-ray beam passing slightly caudal to it, and the film vertical before the face (this is essentially a modified Granger angle). (Fig. 49.) The second position is obtained by rotating the head 90° through its vertical axis,

Fig 52. Postero-anterior view 35° above the base line.

affording a lateral view, the base line remaining horizontal. (Fig. 50.) The third view is made with the head at 90° to the first two. To establish this angle, the head is tilted back with its vertex against the vertically placed film; the base line is now also vertical, the horizontal X-ray beam being projected from beneath the chin. This has the advantage over the old position, with the film under the chin, of throwing the sinus structures into a less obstructed field and affords a "ground plan" of all the sinuses excepting the frontal, which is obscured by the incisor teeth and their alveolar processes. (Fig. 51.) The combination of these three positions for diagnostic purposes is described in a subsequent chapter.

The well-known angles of Waters,[215] Caldwell,[24] Aspray,[8] and others each have their advantages with radiopaques, as

Fig. 53. Postero-anterior view 55° above the base line.

without them. We prefer to designate them in terms of the angle between the base line and the X-ray beam which is always horizontal, irrespective of the relation of the face to the film. (Figs. 52 and 53.)

Some observers adopt one routine position for the seventy-two hour film, which is quite satisfactory. It would seem preferable perhaps to examine the initial films in each case and to repeat after seventy-two hours that view which happens best to interpret the given case.

In difficult cases additional angles add to the diagnostic possibilities, and this is likewise true of stereoscopic studies. Stereoscopic radiography is greatly simplified by the use of the fixation and precision apparatus. However, we prefer to employ routinely the three views described.

The objection has sometimes been raised that three initial films and a seventy-two hour check constitute an examination which is unjustifiably expensive. This has been partly overcome by blocking out the halves of a film in turn, thus economizing in margins and projecting two views on one 8 x 10 film. It would seem, however, that any case which merits a radiological examination of any kind should justify the expense of a thorough one.

CHAPTER XI

THE RATIONALE OF PARTIAL FILLING AND THE HORIZONTAL BEAM

IMPRACTICABILITY OF COMPLETE FILLING—ADVANTAGES OF PARTIAL FILLING—ANGLE OF OBSERVATION—RECOGNITION OF CELLS—TWO SOURCES OF ERROR.

To one unaccustomed to the observation of contrast media in sinuses it would seem fairly obvious that the best results should be obtained from a complete filling of the cavity with the opaque substance; and that this once accomplished, complete and reliable information might be had of the topography of the cavity and of the thickness of its lining membrane. Experience shows this to be neither feasible nor desirable. The diagnostic value of a film is not proportional to the size of the opaque areas or to the contrasts they present.

Films made under these circumstances, although the X-ray technic may be flawless, are full of pitfalls to the thoughtless observer in that they often misrepresent the contours of overlapping cells and they may indicate a thickening of membranes where none exists. It is not uncommon to encounter in contemporary journals published roentgenograms purporting to demonstrate polyps and other pathological filling defects which are undoubtedly air bubbles.

IMPRACTICABILITY OF COMPLETE FILLING. To begin with it is next to impossible to accomplish a complete filling by any method whatever. It is an incontrovertible physical fact that *no sinus can be filled with fluid above the level of its ostium*, at whatever level that may be at the moment of filling, by any

known method. There follows the corollary that complete filling can be brought about only when the ostium is at the exact top of the cavity; and who shall say in what position a particular head is to be placed in order to bring this about?

To exemplify, suppose that it is required to fill an antrum through its normal opening, and that the opening is, in this individual, at a point on the wall 1 cm. from the top. The cannula is inserted into the opening and the fluid proceeds to fill the sinus until it reaches the ostium, through which it overflows; and no amount of pressure or any other expedient will accomplish any filling beyond this point because the air imprisoned in the vault above the ostium cannot escape.

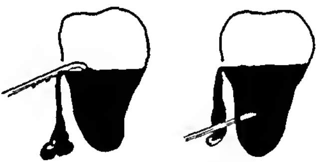

Fig. 54. Left, cannula in the ostium. Right, needle puncture. *In either case filling ceases when fluid reaches the level of the ostium, because air above it cannot escape.*

This fact is commonly overlooked, even by some experienced workers. In an early article,[98] the following statement appeared: "The extremely *heavy oil* [*iodized poppy-seed oil* diluted 2-1 with heavy liquid petrolatum] makes filling above the level of the ostium possible. Dry cotton is immediately packed in the middle meatuses and the patient sent two *floors* away for roentgen examination." This statement exemplifies the common misapprehension regarding the true cause of failure to accomplish filling above the ostium, and attributes it to the

oil's escaping after introduction, as indicated by the precautionary packing. Why then do the roentgenograms not reveal the imperfect filling? The answer lies in the angle of exposure. Although it is not stated in the text, illustrations accompanying the article indicate that the exposures were made with an almost vertical beam so that there is no means of determining from the roentgenograms whether the cells were completely filled or not. (Fig. 55.) The danger of this technic lies in the fact that if the air bubble here shown were slightly larger, the shadow would simulate a filling defect which does not exist.

The amount of air above the level of the ostium determines the degree of failure to complete the filling. It may be contended that this objection is academic, and that in actual practice by shifting the head to place the ostium uppermost this

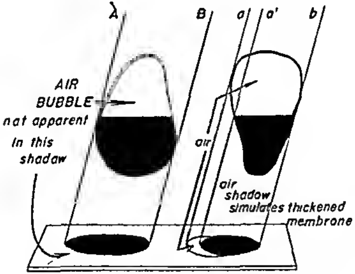

Fig. 55. Diagrammatic explanation of the failure of vertical or nearly vertical beams to detect air bubbles when these are above the widest diameter of the sinus. The figure on the right shows how incomplete filling may in this position simulate thickened membrane, when the fluid level is below the widest diameter.

error can be made so small as to be negligible. (Fig. 56.) This is often, but by no means regularly the case, especially in cells such as the ethmoid labyrinth, in which the ostia are extremely variable in their positions.

When the fluid is introduced through a puncture wound by means of a needle, the same train of events occurs (Fig. 54): the fluid spills out at the ostium and no manipulation, save only the placing of the ostium at the exact top, can result in a complete filling. In this case the added opening permits the fluid to escape relatively quickly, aided by the excursions of respiration. I am aware that opaque oil may remain in an antrum for days in spite of the presence of a puncture wound, but quite as often it does not, and one cannot be sure that it will.

Fig. 56.

The presence of an incomplete septum, not infrequently encountered, which partly divides a cell into two chambers, further complicates the situation by adding another "air dome" which cannot be filled. (Fig. 57.)

It is unnecessary to follow the idea further, except to insist that the assumption that a cell is completely filled when this may not actually be the case opens the way to diagnostic errors.

Advantages of Partial Filling. Fortunately a deliberate partial filling yields various types of information not to be had from complete filling and is at once the method of necessity and of choice. In order to elucidate these advantages it becomes necessary to discuss first the use of the horizontal X-ray beam in making the exposures, as partial filling and the horizontal beam are largely interdependent in their functions.

Angle of Observation. Fluid opaque media in sinuses should not be regarded as something apart, behaving in new and uncertain ways, but as fluids in any rigid containers, obeying the simplest physical laws, and capable of observation in customary ways. No one would think of examining a fluid in a transparent container, such as a bottle or a test tube, by peering down upon it through the neck. Nor would he look up at it through the bottom of the flask with a bright light above it, although this is the view ordinarily obtained in the roentgenograms when the film lies horizontally beneath the sinus and the rays pour down vertically from above.

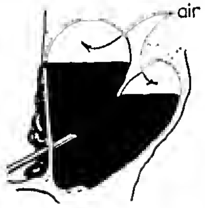

Fig. 57. Effect of a partial septum upon the filling of an antrum.

The accepted way of looking at the fluid in the flask, to observe any irregularities in the density of it and to examine the thickness of the flask and the contours of it, is from the side, and with the light behind it; and the same applies to fluid media in sinuses. (Fig. 58.)

In this position one is enabled to follow the planes of contact between the container and the fluid at the points where they are inevitably approximated by gravity. If at this interface a discrepancy or "filling defect" occurs, air bubbles and *other artifacts of filling can be definitely excluded.*

Recognition of Cells. In a general filling of all sinuses, from which the greatest amount of useful information is obtained, partial filling and the horizontal beam serve another important purpose, that of distinguishing individual cells from

their neighbors. In such a general filling a certain amount of overlapping occurs, especially between the posterior ethmoid groups and the sphenoids.

Three or four such overlapping cells, viewed from above, present a conglomerate mass of rounded contours casting a shadow in which it is impossible to distinguish either the number or the contours of individual cells. (Fig. 59V.) When these same overlapping cells are only partly filled and are

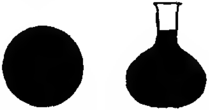

Fig. 58. Shadows of a partly filled flask, vertical and lateral.

viewed from the side (with the X-ray beam as nearly in a plane with the surface of the fluid as possible) each cell may be distinguished by its proper fluid level from its fellows. The shadow of each cell now presents a rounded contour with a flat top. (Fig. 59H.)

In examining strange films it is the presence or absence of these flat tops which immediately indicates to one whether the exposure was made with a horizontal or a vertical beam, and *no reliable identification of a filling defect can be made without this knowledge.*

As this is the chief source of error in the X-ray diagnosis of hyperplasia it may be well to enlarge upon it. If an ovoid translucent chamber be filled to some point above its widest diameter with opaque fluid and illuminated from above, its shadow will be a single homogeneous one, reproducing in con-

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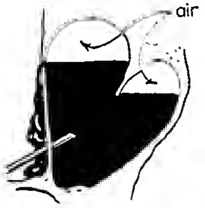

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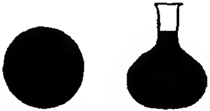

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3. A vertical view, in which the central beam traverses the head perpendicular to the base line from underneath the chin, and the film is placed above the vertex parallel to the base line.

4. The fronto-nasal position, which outlines the frontal sinuses to advantage;

5. The nose-chin position of Waters for the maxillary sinus;

The angles were accurately maintained by means of Ernst's precision apparatus.

The Frontal Sinus. Although, according to Loeb, great diversity of shape occurs in frontal sinuses, there is a comparative uniformity of shape and size in the two frontals of the same head. Extremes of size here are greater than in other locations. Schaeffer[180] pictures a skull from an adult male in which the frontal sinus occupies the entire transverse diameter of the vertical portion of the frontal bone, invades the temporal bones and the great wings of the sphenoid and in which the total capacity is 38 mils. Lyman[125] has opened frontal sinuses which extended upward 9 cm. above the orbital ridge and laterally 4 cm. beyond the orbits, the approximate width of each sinus being 10 cm. The greatest antero-posterior depth was 1.8 cm.

Supernumerary frontal cells are not uncommon. Cryer[33] reports five and Schaeffer six in one skull, in which each sinus was independent of the rest and had its own ostium of communication with the frontal region of the middle meatus.

True absence ol the frontal sinus is rare, although there is frequently an absence of pneumatization of the frontal or vertical portion of the frontal bone. Whatever be the anatomical classification of these rudimentary cells in the horizontal plate, surgically they are equivalent to ethmoidal cells.

The Maxillary Sinus. Maxillary sinuses are less prone to variations, these being rather extremes of size than of general shape. Propensities to bizarre ramifications are rare. The principal variation in the adult maxillary sinus consists in the failure of development from the infantile type, the cavity lying high up and somewhat mesial to the orbit. The contour of the floor of such a sinus depends somewhat upon the stage of dentition and the uniformity with which the teeth have developed and erupted, the pneumatization of the bone following these structures fairly closely. The floor of the sinus is commonly below the level of the nasal floor and should not be confused with it in the lateral view when radiopaques outline both structures. In a thick, poorly pneumatized maxilla, the sinus floor may not extend below the level of the nasal floor. Two levels dorso-ventrally are not unusual, the dorsal one being somewhat above the ventral. A drop of opaque oil hanging from the posterior end of the middle turbinate may conceivably be mistaken in the lateral view for this condition.

In the vertical ("ground-plan") view, the maxillary shadow is invariably the most lateral of the group. The shadow with partial filling usually presents an even ovoid contour at the level of the posterior edge of the vomer, beginning mesially at the wall of the nose and becoming obliterated laterally by the molar teeth. It is unlikely to be confused with other sinuses, even in this position, as it can always be identified by its relation to the teeth, or in their absence by its distance from midline. Posterior ethmoid and sphenoid shadows sometimes partly overlap it, but always extend mesial to it.

Septa in the antrum may vary from mere ridges to crescentic barriers which form definite retentive pockets or they may rarely divide the sinus into two cavities communicating separately with the middle meatus. In this case, the partition may

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The angles were accurately maintained by means of Ernst's precision apparatus.

The Frontal Sinus. Although, according to Loeb, great diversity of shape occurs in frontal sinuses, there is a comparative uniformity of shape and size in the two frontals of the same head. Extremes of size here are greater than in other locations. Schaeffer[180] pictures a skull from an adult male in which the frontal sinus occupies the entire transverse diameter of the vertieal portion of the frontal bone, invades the temporal bones and the great wings of the sphenoid and in which the total capacity is 38 mils. Lyman[125] has opened frontal sinuses which extended upward 9 cm. above the orbital ridge and laterally 4 cm. beyond the orbits, the approximate width of each sinus being 10 cm. The greatest antero-posterior depth was 1.8 cm.

Supernumerary frontal cells are not uncommon. Cryer[35] reports five and Schaeffer six in one skull, in which each sinus was independent of the rest and had its own ostium of communication with the frontal region of the middle meatus.

True absence of the frontal sinus is rare, although there is frequently an absence of pneumatization of the frontal or vertical portion of the frontal bone. Whatever be the anatomical classification of these rudimentary cells in the horizontal plate, surgically they are equivalent to ethmoidal cells.

The Maxillary Sinus. Maxillary sinuses are less prone to variations, these being rather extremes of size than of general shape. Propensities to bizarre ramifications are rare. The principal variation in the adult maxillary sinus consists in the failure of development from the infantile type, the cavity lying high up and somewhat mesial to the orbit. The contour of the floor of such a sinus depends somewhat upon the stage of dentition and the uniformity with which the teeth have developed and erupted, the pneumatization of the bone following these structures fairly closely. The floor of the sinus is commonly below the level of the nasal floor and should not be confused with it in the lateral view when radiopaques outline both structures. In a thick, poorly pneumatized maxilla, the sinus floor may not extend below the level of the nasal floor. Two levels dorso-ventrally are not unusual, the dorsal one being somewhat above the ventral. A drop of opaque oil hanging from the posterior end of the middle turbinate may conceivably be mistaken in the lateral view for this condition.

In the vertical ("ground-plan") view, the maxillary shadow is invariably the most lateral of the group. The shadow with partial filling usually presents an even ovoid contour at the level of the posterior edge of the vomer, beginning mesially at the wall of the nose and becoming obliterated laterally by the molar teeth. It is unlikely to be confused with other sinuses, even in this position, as it can always be identified by its relation to the teeth, or in their absence by its distance from midline. Posterior ethmoid and sphenoid shadows sometimes partly overlap it, but always extend mesial to it.

Septa in the antrum may vary from mere ridges to crescentic barriers which form definite retentive pockets or they may rarely divide the sinus into two cavities communicating separately with the middle meatus. In this case, the partition may

across the midline and envelops the smaller in varying degrees and positions. One cell may be rudimentary while the other entirely pneumatizes the body of the bone. Under such conditions, a cell encroaching upon the opposite side may give rise to symptoms on that side; in fact, they may be confined to it. (See Case No. 7, page 211.) Radiopaques here constitute an invaluable aid in clarifying the topography. Three, or at least two, views are required, as a densely filled larger cell overlapping a small one may completely obliterate it.

The commonest of the diverticula issuing from the body of the bone itself is that resulting from the pneumatization of its pterygoid processes. Unilateral pneumatization of the pterygoid occurs in about 20 per cent of my own cases; bilateral pneumatization is less than one per cent. This peculiarity, when it occurs, constitutes a ready means of identification if any doubt exists whether the cell be a posterior ethmoid or a sphenoid cell. It is prominent in the postero-anterior view, in which it extends laterally and well below the ethmoidal group. (Fig. 85.) In this position the sphenoid presents two fluid levels, one in the body proper and the other in the pneumatized pterygoid. The oil in the body proper is prevented from flowing into the pterygoid lying at a lower level by a bony ridge which always persists and which is more or less clearly defined by the oil. The importance of this ridge lies in the fact that the pterygoid canal containing the vidian nerve courses along its crest. The bony wall under these circumstances is extremely thin; in fact, dehiscences are the rule, and the nerve is protected from sphenoidal inflammations by nothing more than the mucosa.

In the lateral view it appears as a caudo-ventral extension from the body of the sphenoid, somewhat below the level of the main shadow. It is not seen in the vertical view, as in this

position the diverticulum points upward and the oil drains from it into the main body of the sphenoid.

Pneumatizations may also extend into the anterior and the posterior clinoid processes (Fig. 86) and into the ethmoid bone, rarely into the rostrum of the sphenoid.

The variations in sphenoid pneumatization are of much greater diagnostic significance than those in other sinuses on account of their clinical importance; manifestations through the structures upon which they may encroach, namely, the mandibular nerve in the foramen rotundum, the vidian nerve in the pterygoid canal, the nasal ganglion in the spheno-palatine fossa and the collection of cranial nerves and a vein traversing the sphenoidal fissure. "Rarely the sphenoid sinus extends sufficiently far into the pterygoid process of the sphenoid bone to come in contact with the wall of the maxillary sinus. Rarely the ethmoidal extension of the sphenoidal sinus is found to be in actual contact with the supraorbital extension of the frontal sinus."[193]

Schaeffer has given a graphic and detailed description of this region.

The illustrations immediately following clearly demonstrate the angles at which the exposures are made and localize each group of sinuses in each of the five standard positions.

The dark line, Fig. 62, indicates the position of the "base line" connecting the nasofrontal suture with the upper margin of the external auditory canal. The white lines indicate the positions of the central beams in the four exposures made in the sagittal plane, the figures designating the angle in relation to the base line. The lateral view is made with the base line horizontal and the central beam perpendicular to it, also horizontal, and approximately bisecting it.

By comparing these lines and the structures which they traverse with the shadows labeled in the films it can be seen

that the submento-vertical view alone is free from overlapping. It constitutes a veritable ground plan. The lateral view is free from overlapping, so far as the cells of one side are concerned. Each cell naturally conceals its fellow on the opposite side, so that these two views at least are necessary, used in conjunction with one another, to permit interpretation.

The other three postero-anterior midline exposures are for the purpose of disengaging one shadow or another from the mass, and are valuable only in so far as they accomplish this. It will be seen for example that the 55° position (Fig. 71) designed to clear the approach to the maxillary sinus fails in its purpose at the bottom of the sinus where most of the membrane thickening may be expected. On the right side of the illustration a short black line indicates the caudal limit of the sinus. In this region the bone shadows are so dense that they obscure the oil completely and any membrane thickening as well. For this region the 0° position (page 128) yields the necessary information, although the upper portions of the sinus now are obscured by the shadow of the petrous pyramid and portions of the sphenoid bone.

The amount of overlapping which occurs in the 0°, 35° and 55° positions is best demonstrated in the colored diagrams Figs. 64, 70 and 72. In dealing with these regions a check with the lateral or the submento-vertical views (or much better with both) is essential.

If X-ray examinations are to be worth anything at all they must be adequate or they will be actually misleading. A single exposure may occasionally be justified to serve a specific purpose which the examiner has in mind. As a routine procedure purporting to constitute a search for sinus disease it is of negligible value.

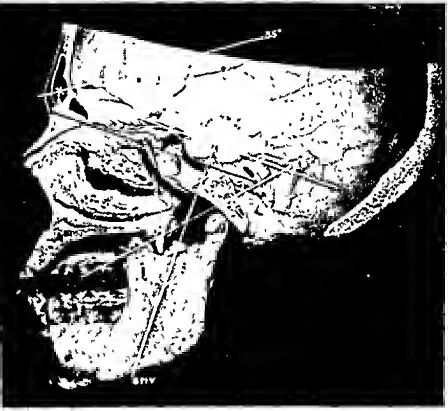


Fig. 62. Sagittal section of a skull showing the base line in black and the beams required for the various positions in white.

X X on the 0° and the 35° lines indicate the anatomical point of importance to each.

V V on the 55° line indicate the lower limit of the maxillary antrum and the petrous pyramid of the temporal bone. Shadows of which should not overlap.

Fig. 63. 0°—Direct Postero-anterior Position The central beam is along the base line The "Granger line", Gr L., is faintly seen above. The ethmoidal capsule is seen end-on With a contrast medium this is the best view for demonstrating the floor of the maxillary sinus.

Fig. 64. Diagram of the preceding. Note especially that the anterior and posterior ethmoids and the central portions of the sphenoid overlap.

Fig 65. Direct Lateral View The central beam bisects the base line, which is horizontal. It is plainly seen that fluid can be made to reach all sinuses provided the proper technic is observed and the ostia are open.

Fig. 66. Diagram of the preceding. Noté that there is little overlapping except of cells of the opposite side.

Fig. 67. Submento-vertical View. The central beam is perpendicular to the base line. Since each cell is completely visible, this view is the most useful in determining emptying time.

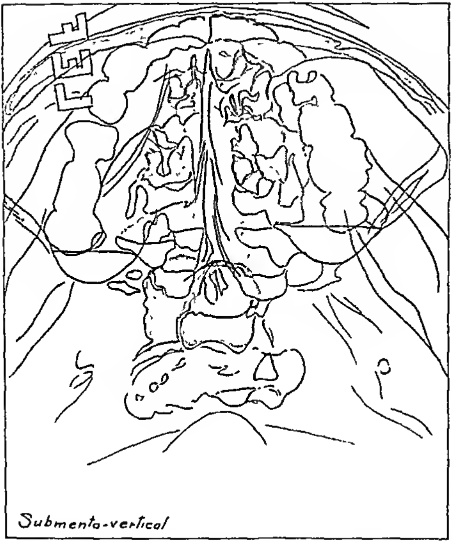


Fig. 68. Diagram of the preceding. It is not possible to distinguish accurately the posterior limits of the frontal sinus since these are obscured by the teeth—see opposite.

Fig 69 35°—Frontal Position. This is the best position for demonstrating minor abnormalities of the outlines as well as densities since the frontal sinus is brought close to the film and conflicting shadows are thrown out of the field Note the pterygoid canal on each side and compare with Fig 74

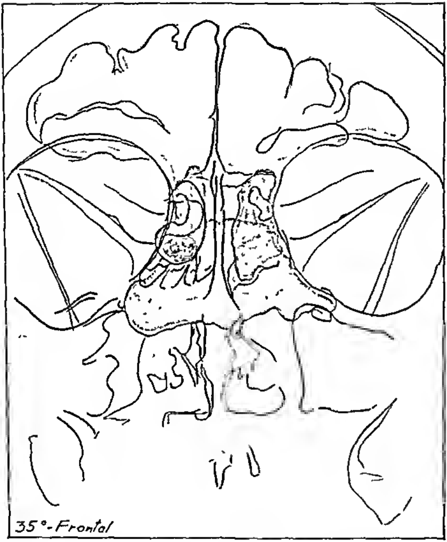


Fig. 70. Diagram of the preceding. The frontal sinuses, except for their ducts, are unobstructed. Although the shadows of the anterior and posterior ethmoid cells overlap less than in the 0° position, their walls are seen on a long slant; there is foreshortening and lack of detail. The sphenoid shadow still completely overlaps that of the posterior ethmoid.

Fig. 71. 55°—Maxillary Position, best adapted for the study of the body of the maxillary bone and sinus. The floor of the sinus is obscured by the dental processes and the teeth. Filling defects in this location are commonly overlooked unless other positions are resorted to.

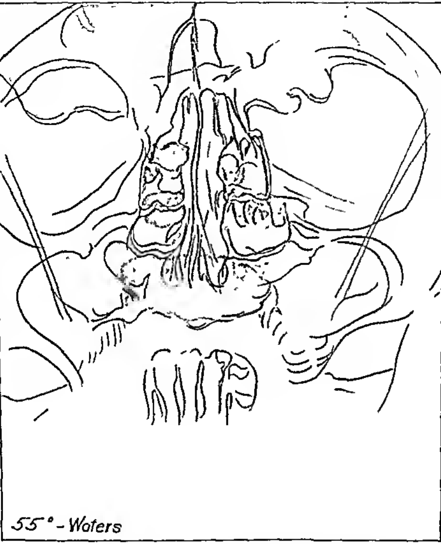


Fig. 72. Diagram of the preceding. The shadow of the floor and the body of the sphenoid is disengaged from those of the ethmoids and stands out clearly.

A B C

Fig 73 Lateral views of a sphenoid cell, with pneumatized posterior clinoid processes. (A) plate without lipiodol, (B) plate with lipiodol, exposure in the supine position, as indicated by the oil levels. (C) the same in the erect position. The fact that the oil remains in place in this position indicates a narrow communication between the clinoid and the main cavity. (Case of Dr. W. V Mullin, who supplied the plates and kindly permitted their publication.) (positive print)

Fig. 74. Bilateral pneumatization of the pterygoid processes of the sphenoid (positive print).

Fig. 75. Lateral view showing the large triangular shadow characteristic of the dorsal posterior ethmoid cell (positive print.)

Fig 76. Diagrams after Loeb to show the symmetry of the sphenoidal group in spite of the disparity of size and position of the individual cells.

CHAPTER XIII

CELL IDENTIFICATION: THE T-SQUARE METHOD

ACCURATE COMPARISON OF VIEWS—ALLEN'S TABLE.

The confusion which arises concerning the identity of cells in certain locations when these are filled with radiopaques indicates that there must be a considerable element of error in routine diagnoses made without their assistance. Cell partitions are often paper-thin, and while they may appear as sharp lines upon the radiograph when approximately parallel to the X-ray beam, they may vanish altogether if they happen to be at a wide angle to it. There is such a multiplicity of fine lines and shadows in an X-ray of the skull that it is difficult to select the truly defining outline. The roentgenologist, at least the experienced one, is ready to admit this. He points out, further, that even with a few drops of a radiopaque to accent them, their identity is not always clear.

ACCURATE COMPARISON OF VIEWS. Stereoscopic views go far to remedy this difficulty, but even they do not always overcome it. In such an extremity, one naturally compares various views of the cell in as many positions as possible—he looks at it from all sides. This comparison is made consciously or not, at any examination, but by accurately angulating the views, each at 90° to the others, it can be made with mathematical accuracy. To this end, Allen[2] has devised a simple table (Fig. 78), in one end of the top of which is placed a 14 x 17-inch plate glass flush with the surface. Under the glass are two side shelves which just receive the edges of a

CHAPTER XIV

FILM INTERPRETATION: SHADOWS IN GENERAL

PROVINCE OF OPAQUE INJECTION—NORMAL SHADOWS SHADOW DENSITIES—OUTLINE—CELL IDENTITY—UNCERTAINTY OF DEFINITIVE BONE SHADOWS — OIL SHADOWS—MEMBRANE SHADOW OUTLINES.

Opaque injection is not recommended as the solution of all problems of sinus diagnosis. It is an adjunct, not a substitute. There are conditions in which a simple radiograph yields more and clearer information than one with radiopaques. Consideration of the former is here omitted, only because it is a subject to itself and does not fall within the scope of this book.

It is not recommended that anyone confine his radiography to opaque methods, although in my own experience there is little to be derived from the simple film which cannot be deduced from an injected one, *provided that one is content with moderate partial filling, and does not insist upon obliterating the entire wall texture by filling the cell to the top.* There are, on the other hand, many things to be learned from an injected sinus which an empty one cannot reveal.

Interpretations from radiopaques should be regarded neither as being so simple that anyone familiar with radiography can make them offhand, nor so troublesome and tedious as to make them impractical.

Whether the use of radiopaque substance adds anything to a radiograph or not has been discussed far and wide. My own

conclusion is that some radiologists are stating the truth when they say that they cannot uncover any additional information through the use of radiopaques. On the other hand, I am convinced that others can and do. Of the first group, not one, so far as I can discover, makes any reference to the physiology of the sinuses. Granted, as I have often repeated, that the topography of the sinus—bone, membrane and exudate—is an open book to these men, there remains still the question of the ability of the sinus to empty itself, which can be determined only by watching it do so. And this is what the rhinologist requires, above all else, to know. If anyone has succeeded in determining this without radiopaques, I can find no mention of it in print.

Much of the adverse criticism of the use of radiopaques has come, as may be seen by studying some of the published illustrations, as the result of faulty technique or through a misconception of what is to be expected. In the early days, the chief trouble was the use of the X-ray beam projected vertically upon the pool of oil.

The thoughtful roentgenologist is not turning his back upon opaque injection, but is regarding it, however circumspectly, as a medium worthy of his careful scrutiny and development.

There are things which the postmortem examination cannot reveal, for the study of which radiography is indispensable: the flap-valve action of a swollen ostium; the suddeness with which an allergic membrane swells and obliterates a sinus cavity and subsides again to its normal state. The most fundamental of the unanswered questions cannot be referred to the pathologist because, by their very nature, they involve living membranes.

PROVINCE OF OPAQUE INJECTION. Two special types of information are to be derived from the use of fluid radio-

Fig. 79. Oil shadows indicating (1) normal membranes in the sinuses on the right side, and (2) thickened membranes on the left.

paques: the exact nature of the cell cavity, and the readiness with which drainage is effected through its ostium.

The shadow cast by the ordinary radiopaques exceeds in density almost any shadow cast by bones. The body of the sphenoid in the lateral view is the possible exception. Here it is sometimes difficult to outline the limits of the oil, lying on the floor of the cavity, and reference must be made to a postero-anterior view.

Owing to the pronounced contrast of the oil shadow to its surroundings, hence the ease in identifying it, unusual angulations and positions sometimes resorted to in order to avoid overlapping and to emphasize particular structures are unnecessary. Refinements of exposure, however, should be maintained

as the grades of density found in the upper portions of cells and in cells which refuse to fill are of service.

NORMAL SHADOWS. In the case of a normal sinus the oil shadow conforms closely to the bone shadow. There should be a thin even line, or zone, of light between them, which should not be interpreted as beginning hypertrophy. (Fig. 79.) The normal mucosa varies in thickness from .5 mm. to 1 mm.[232] If the sinus is five inches from the film and the source of radiation is thirty inches from it, the gray shadow cast by the normal 1 mm. mucosa will be 1.2 mm. wide. The absence of this line has no significance, inasmuch as it is readily obscured by any slight inequalities in the cell wall. There is no diffusion or diffraction of X-rays by bones or the halogenated oils, hence no allowances need be made for such aberrations.

SHADOW DENSITIES. Inequalities in the density of the oil shadow do not necessarily indicate pathological conditions, as the cells are often uneven in section. But certain types of inequality should be regarded with suspicion. Definitely circular or ovoid areas of decreased density may be either polyps or air bubbles. If the exposure is made with the beam horizontal and the film vertical, bubbles can be eliminated. It is not usual to see such an area in the center of an oil shadow, which aids in its identification. A general irregularity of density, or mottling, indicates pronounced general thickening of the membrane, and is likewise associated with a corresponding irregularity of the shadow margin. Variations in density are sometimes due to small ridges or septa of the walls found chiefly in the frontal sinus and in the antrum in the region of previously erupted teeth, but these present fairly characteristic outlines and are not easily confused with disease conditions.

OUTLINES. More significant than shadow densities are shadow outlines, indicating the topography of the cell, and

Fig. 80. Roentgenogram illustrating the difficulty of establishing the identity of the posterior cells, even when outlined with radiopaques. Comparison with the other views is here imperative

even to the most experienced interpreter of sinus films radiopaques offer a revelation, in topography alone. (Fig. 80.) In spite of the disclosures of the dissecting room, one is apt to regard sinuses, viewed on X-ray films, as more or less symmetrical cavities, and while the vagaries of the frontal sinuses and the antra are obvious enough, when it comes to the delicate traceries of overlapping ethmoids and sphenoids one is prone to select from among the network of lines those which most nearly satisfy his mental textbook image of the group. The use of radiopaques shows how erroneous such localization may be. This is typified by the patient in Case 7, Chapter XX, whose right-sided headache was relieved only after exenteration of her left sphenoid.

CELL IDENTITY. The variations in size and relation of the posterior ethmoid cells and the sphenoids are especially great. The published tables indicate, for instance, that of so many hundred sphenoids measured the dimensions varied within certain limits and that the ethmoids varied within certain other limits. They seldom emphasize that in a particular instance, in which the right sphenoid is very small (a mere dimple measuring a few millimeters), the posterior ethmoid on the same side or the opposite sphenoid is large enough to reach around and take its place, and that in such a case exenteration of the little sphenoid, no matter how thorough, might easily be totally unavailing. It is put forth that any good rhinologist knows this, and has only to consult his X-ray film (not merely his roentgenologist, please) to ascertain the state of affairs existing in the case at hand. Experience does not bear this out. In the roentgenograms illustrated, for instance, it was totally impossible to determine the relations, not to mention the identities, of the posterior cells without radiopaques, and even with them it proved difficult until various views were compared. Practicability steps in and demands, "What difference does it make, which cell is which, in as much as all of them require treatment anyway?" One does not believe that the present state of our knowledge warrants this attitude; in fact, one wonders whether the attitude is not engendered by our present inability to incriminate individual sinuses. If, for example, there were no exact means of distinguishing one tooth from another, what reckless extraction would result!

The shape of a sinus cavity, and more especially irregularities in its outline, may entirely obliterate the pale zone cast by a thickened membrane. These irregularities, producing a multiplicity of bone and membrane densities through which the X-ray must pass, cast shadows which are deceptive and which

introduce an element of uncertainty into every diagnosis based on the sharpness of shadow margins.

UNCERTAINTY OF DEFINITIVE BONE SHADOWS Diagnosis depending upon the relative sharpness of outline of a given cell, especially when this is supposed to be due to freedom from fluid or hypertrophied membrane, is often fallacious. To begin with, the shadow of the fairly flat wall of a rhomboidal sinus must normally be sharper and less diffuse than the shadow cast by the constantly changing curve of a more ovoid sinus wall. (Fig. 81.) In the former case one beam passes through a large quantity of dense bone and its immediate neighbor passes through an air cavity. The result is a sharp line. In the second case, the first beam also passes through a fair mass of bone tissue, but its adjoining beams pass through progressively decreasing bone masses and concomitantly increasing air spaces, thus producing a graded or "fuzzy" shadow which is obviously not a sign of pathology. It is also risky to depend for a diagnosis upon the coaptation of exudates to bone for the diffusion of a shadow. It is scarcely conceivable that a thin film of exudate can have any such effect. Large masses of exudates, as they are observed in sinuses at operation, are so viscous and tenacious that ordinarily they do not quickly slide about in the sinus with a change of head position. Sinuses presenting hazy outlines are frequently shown at operation to be lined with thin normal membranes.

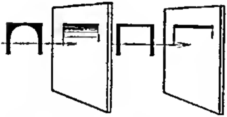


Fig. 81. Diagram demonstrating how the conformations of normal cavities may influence the sharpness of their shadow outline.

One should say, rather, that the acuity of the shadow depended more upon anatomical conformations, and upon the *nature* of the pathological conditions of the membrane, of the periosteum and the bone, than upon the mere thickening of the mucosa. Referring to the films of both cases cited in the chapter on Allergy, in which the antral mucosa swelled from normal to many times that thickness overnight, one had the opportunity of studying the same sinus walls with and without thickened membranes, all in the course of a few hours; also before, during and after radiopaque injection. In this case, the original films show sharply defined cell outlines previous to any use of radiopaques. The normality of the membrane was verified by oil injection, the bone and oil shadows coinciding sharply and continuously. After the asthmatic attack, the membrane increased in thickness until the cavity of the antrum was half obliterated. The membrane was now approximately 1 cm. in thickness, but shadows of the bone beneath retained their original sharpness of outline. This was logically to be expected. It is presented, in passing, to refute the contention that the interface between bone and air creates a sharper, more definite shadow than the interface between the same bone and fluid or membrane. It goes without saying that this discussion refers entirely to membrane-to-bone shadows and does not apply to actual bone rarefaction which naturally casts a diffuse shadow.

Oil Shadows. However, the broader questions of bone shadows belong in another place. Equally characteristic are the oil shadows, which concern us here. Their outlines in the normal sinuses are even and continuous. When they are broken it is only in large contours, determined by the lobulations and ramifications of the cell, such clinoid and pterygoid pneumatization of the sphenoid, and pouches in the floor of the antrum. The single exception is the anterior ethmoid, whose cells are

so small and irregular as to produce normally a scattering of small, irregular oil shadows. But even minor thicknesses of the ethmoidal mucosa may be detected. (Fig. 35.) As has been indicated, the oil shadow on the floor of the sphenoidal sinus, as seen in the lateral view, is often quite indefinite owing to the thickness of the bone in that region and to the overlapping of the two oil shadows (right and left). Even from this view some information can be gathered: the relative sizes of the two sphenoid cells and the degree of pneumatization of each; their locations relative to one another, which is seldom feasible in a direct lateral view without radiopaques; and in cases of pituitary involvement, the state of the sella and its clinoid processes, which may be pneumatized to their tips. (Fig. 73.)

It may be well to note briefly a few of the characteristics of membrane outlines which are of diagnostic importance. Aside from the density and thickness of the membrane, its outline as related to the bone outline is indicative of the pathologic change present.

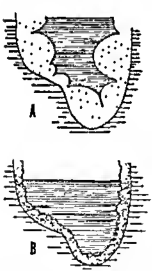


Fig. 82. Diagrammatic representation of mucosal contours in contact with radiopaque.

A. Acute infection or allergy. B. Hyperplasia.

An edematous membrane, an allergic one, or one acutely inflamed, swells relatively suddenly[12, 37] (See Chapter XVIII.) The connective tissue network of the submucosa yields here and there in the areas of least resistance, producing a group of surface bulges. The resulting shadow is a series of convexities distributed more or less at random. The important character of such an

outline is that it does not run parallel to the adjacent bone shadow, in fact it usually has no relation to it. Such a membrane does not ordinarily cast a very dense shadow, unless there is some previous hyperplasia.

A hyperplastic membrane casts a different shadow. Its submucosa is thickened rather than swollen. Its connective tissue binds it down so that the surface is pebbled rather than ballooned. This pebbling also casts an irregularly outlined shadow, but the irregularities are small, compared to the foregoing, and the whole outline parallels the underlying bone outline. The shadow cast by this membrane is relatively dense.

It is characteristic of a normal sinus to fill cleanly and empty cleanly; that is, the margins are sharp in both the initial and 72-hour films. Abnormal membranes frequently cause the oil shadows to take on a flecked appearance. This is usually associated with delayed emptying, but not invariably.

CHAPTER XV

FILM INTERPRETATION: SELECTIVE FILLING AND EMPTYING

VISUALIZATION OF FILLING AND EMPTYING—ROUTINE OBSERVATIONS—FAILURE TO FILL—FAILURE TO EMPTY—SELECTIVE FILLING AND EMPTYING—SEVENTY-TWO HOUR INTERVAL FILM—MODIFYING CONDITIONS—PRACTICAL DEDUCTIONS.

Previous to displacement radiography, with or without radiopaques, yielded information only as to the physical characteristics of sinuses, that is to say, their static qualities: size, shape, density and location. From anatomical and surgical standpoints this information is of great value and directly to the point. But the introduction of fluid radiopaques supplies, in addition, a simple and facile means of visualizing the physiology of a given sinus in so far as its drainage is concerned. The importance of this information is difficult to overestimate, since these functions of drainage and ventilation, more than any other thing, constitute the determining factor between health and disease, chronicity and cure, treatment and operation. If it is possible to observe accurately the spontaneous drainage of each individual sinus before operation, the contemplated procedure can be more intelligently evaluated and much needless surgery can be avoided. The behavior of fluid radiopaques in entering and leaving the uninjured sinus by natural means has proven a reliable index of the eliminative function of the cell.

VISUALIZATION OF FILLING AND EMPTYING. It is admitted that in its physical characteristics the oil differs somewhat from the secretions or exudates of which information is sought, but in viscosity and specific gravity it sufficiently resembles

these exudates to simulate closely their passage through constricted openings, through small tubes and down moist inclined planes. Indeed it is not strictly necessary that the indicator shall have the same composition as the fluid it simulates, any more than that other functional indicators, such as tetra-iodo-phenol-phthalein in the liver or phenol-sulphone-phthalein in the kidney need resemble the secretions of those organs. If the normal or average retention time of a given radiopaque is known, relative celerity or delay in emptying can be detected.

It is a first consideration, if one's conclusions are to be of any value, that the mucosa must be undisturbed in the process of introducing the oil. Since this cannot be administered intravenously or *per os*, but only by direct injection, this must be accomplished without previous medication or instrumentation. Cocainization is out of the question, as the initial over-patency of the ostium following its use results in an increased drainage immediately after introduction, and the subsequent turgescence in an adventitious retention. This precludes injection through any puncturing instrument and at least contraindicates cannulization, as manipulations with cannulæ in searching for the ostia in uncocainized meatuses may traumatize the tissues or set up vasomotor reactions sufficient to vitiate the results. Sinuses which permit easy cannulization under these conditions are rarely the ones which require investigation. It may appear that undue emphasis is here attached to the results of minor traumata, but anyone who has had occasion to manipulate the sinus mucosa in living animals can testify to the severity of the submucosal edemas and often hemorrhages which follow the slightest contusions.

Displacement has been found to meet the requirements, as there is no contact of instruments with the membranes, and the conditions of introduction can be accurately standardized and

controlled; that is to say, such factors as viscosity, the degree of vacuum and the amount of fluid can be kept constant.

ROUTINE OBSERVATIONS. Practical diagnoses may be made from the readiness with which individual cells are entered by the oil, and by the time required for its spontaneous emptying. The radiopaque is introduced by the usual displacement technic and the relative filling of cells is observed from these initial X-ray films. All static, topographical variations are also noted from these first films. If further skiagraphs are now made after an interval, the facility, relative and absolute, with which spontaneous drainage occurs can be accurately determined. (Figs. 84 to 89.) In the author's experience clinical observations have confirmed X-ray findings of this nature more frequently than those of simple radiography.

The factors which determine the entrance of the fluid into a cell are suction, submersion of the ostium, patency of the ostium and presence of air in the cell. The first two are readily controlled. If, when suction is applied to one nostril, the opposite ala collapses under the closing finger, negative pressure exists throughout the nose. Submersion of unobstructed ostia can be assured by maintaining the head in the proper position and filling the nasal chambers with oil of suitable fluidity. If filling now fails to occur, this failure must be attributed to one of the remaining factors, an obstructed ostium or absence of air in the cavity, due to polyposis or exudation. Objection could be made that an ostium was obstructed by some external agency, such as a hypertrophied turbinate or a septal deviation, which is true, but this in itself constitutes a pathological condition interfering with drainage which, after all, is the object of the search.

MINIMAL FILLING IN A NORMAL SINUS. A situation exists in which a minimal filling occurs in a normal, well-venti-

lated sinus; this is the case when the ostium is at the exact bottom of the cell at the moment of filling. In this situation at the first application of suction air is exhausted and replaced by oil. At the second application, the oil is promptly withdrawn but again returns on relinquishing the vacuum. Thus with each alternation of normal and negative pressures, the oil is drawn in and out. The final alternation ceases on the ingoing phase, and a small amount of fluid is retained. In view of this possibility, the relative degree of filling should be disregarded in sinuses in which there is any likelihood of the ostium having been at or near the bottom at the moment of filling. Fortunately, the relative emptying time is not determined by the position of the ostium and can be relied upon.

To particularize: in the exaggerated supine position, the sphenoid ostia lie approximately at the top of their respective cells, and under no circumstances could they lie at or near the bottom, occupied in this position by the sella turcica. If now oil fails to enter, especially if it enters surrounding cells, this failure cannot be attributed to the position of the ostium, lack of suction or non-submergence. If in the same position minimal filling occurs in an antrum, it is probably due to the dependent position of the ostium and should be disregarded from a quantitative standpoint. But these minimal fillings are reliable in the estimation of drainage time, for they may be retained indefinitely by a diseased antrum.

If sufficient fluid has been introduced and even a single cell fills well, it may be reasonably assumed that there has been no error in technic; the vacuum must have existed in all parts of the nose to the same degree, and the relative filling of the cells must be due entirely to their physical characteristics, anatomical or pathological. It should not, therefore, be assumed by a beginner that failure to fill is due to some oversight on his part.

as he has no control over the mechanics of the nose beyond providing the fluid, the vacuum and the position.

FAILURE TO FILL. It requires an obstruction of fairly obstinate nature to prevent the escape of air bubbles from a cell under a negative pressure of 180 mm., so that absolute failure to fill may be generally regarded as being due to such an obstacle. (Figs. 83 and 90.) This is commonly some struc-

Fig. 83. A single cell fails to fill.

tural blockade, as of an impacted septal ridge, a hyperplastic turbinate, a polyposis or some type of synechia. The flap-valve action of the edematous mucosa in allergic conditions is especially effective in preventing filling. Complete failure of all cells to fill is so rare and, when it does occur, is so frequently associated with allergy that the author has come to regard it as reasonably indicative of this condition.

In pansinusitis with advanced turgescence, practically complete failure to fill may occur, but even here small droplets of oil usually manage to enter, and there is not the picture of complete failure which so often occurs in allergy. It is conceivable that in allergic states the cells may be filled to overflowing with thin mucoid secretion and that for this reason they do not show even traces of oil. Whatever the reason, the complete failure to fill may occur in allergic individuals whose noses are normal to inspection and is so striking that it cannot be regarded as accidental.

FAILURE TO EMPTY. Far more sensitive than the failure to fill and really more indicative of the functioning of the physiological eliminating factors, is the estimation of emptying time. In the normal individual, the time required for the spontaneous elimination of a specific fluid does not vary greatly, and if a single radiopaque be consistently employed accurate conclusions may be reached. After a generalized displacement filling, for example, with Brominol Light (low viscosity) in normal individuals, the spontaneous emptying time was found to be of the following order: twenty-four hour films indicated a retention of about one-half the amount originally introduced; forty-eight hour films, a half of this again; seventy-two hour films, little more than a mere flecking, and in ninety-six hours the cells were empty. (Oils of a viscosity of 30 required twenty-four hours longer.) Minor variations, whether faster or slower, seem to have no diagnostic significance when the variation is general. Variations in individual cells, in contrast to the general group, are, in the author's opinion, the most reliable diagnostic indications in the entire field of sinus radiography.

SEVENTY-TWO HOUR INTERVAL FILM. To avoid the inconvenience, expense and possible danger of frequently

Fig. 84 Typical postero-anterior view, first film.

repeated X-ray exposures, it was found advisable to eliminate some of the intermediate exposures and to confine the observations to the initial group of films and a single supplementary one at such an interval as to afford the maximum information. The seventy-two hour film appears now to fulfill these requirements, in that sufficient time has elapsed to give a clear idea of the drainage, although sufficient oil is still retained to assist in cell identification. At one time a series of patients was injected with oil which had been colored deep green with fat-soluble chlorophyll. By this means it was possible to keep visual account of the presence and distribution of oil in the nose

Fig. 85. Typical postero-anterior view, seventy-two hour film.

at intervals. The patients were instructed to return for final roentgenograms when they were no longer able to detect any of the green coloring in their handkerchiefs, this being regarded as an indication that spontaneous drainage had ceased. They returned almost invariably upon the third day, which suggests that observations made before the seventy-two hour period are likely to prove unreliable. Allusions to "final films" in this work, therefore, refer to the routine seventy-two hour interval film unless otherwise stated.

When a general delayed emptying occurs, it is usually very pronounced. In such instances there is little difference between

Fig. 86. Typical lateral view, first film.

the original film and the seventy-two hour one. These cases are comparatively rare. Ordinarily the seventy-two hour film shows complete emptying or retention in one, two or more cells. Such retention is particularly striking and significant when, after a group of cells has been well filled, a portion of the group subsequently empties completely and another portion does not. It occurs not infrequently when in the midst of an average generalized filling a given cell fails to fill while its neighboring cells do so, that the seventy-two hour film shows a much delayed emptying in those cells which filled. It seems reasonable to assume in such cases that the pathological condi-

Fig. 87. Typical lateral view, seventy-two hour film.

tion has completely blocked the non-filling cell, and has at the same time moderately obstructed the others, not preventing filling but interfering with prompt emptying. (Figs. 93 and 94.)

Modifying Conditions. Between two opposite sinuses, both filling, such as, for instance, the right and left maxillary, another factor may be involved in the disparity of drainage, namely, the sleeping posture of the individual. While it has lately been affirmed[11] that no individual posture is maintained throughout the night by a healthy person, there is little doubt that many individuals sleep habitually on one side or the other.

Fig. 88. Typical vertical (ground plan) view, first film

In such persons, postural drainage never occurs on the dependent side throughout the twenty-four hours, whereas the opposite side is drained by this means (and through respiratory oscillations by what virtually amounts to displacement) throughout the sleeping hours.

Emptying time appears to be little affected by normal anatomical variations, however extreme, in the healthy individual. It should not be expected that the subdivisions and segmentations of the frontal sinus, for example, would materially affect its emptying in the erect posture, for the reason that its drainage

Fig. 69 Typical vertical (ground plan) view, seventy-two hour film.

is normally downward. In the sphenoid, however, it might be supposed that the ramifications produced by pneumatization between the pterygoid plates through restricted openings, dependent as they are, would normally require a longer time for drainage. This has not proven to be the case. On the other hand, pneumatized clinoid processes, which normally empty their contents into the main cavity of the sphenoid immediately upon the assumption of the erect position, may retain their oil for several days in the presence of a swollen membrane.

Fig 90. The posterior ethmoid on the *left side fails to fill although the surrounding* cells with the same fluid, position and vacuum fill well.

Practical Deductions. Information derived from the selective filling and emptying of cells has this bearing upon the choice of treatment: in general it may be said that cells which persist in failing to fill at all will probably require surgical intervention, except in cases of allergy in which the local obstruction is the immediate manifestation of a general disease rather than an intrinsic pathological entity. On the contrary, cells which give entrance to even small amounts of radiopaque fluids, without preliminary shrinking or other preparation, may be reasonably supposed to be capable of filling with astringents which should render them progressively more accessible to treatment solutions.

If an operation is contemplated for simple ventilation and drainage, it seems hardly logical to resort to it in the face of a demonstration that complete drainage already occurs. What, if anything, is to be achieved by widening the opening of such a cell?

Fig. 91. Delayed emptying. I. First film shows general filling.

Fig. 92. Delayed Emptying. II Seventy-two hour film of the preceding shows complete retention in the left posterior ethmoid cell, complete emptying everywhere else.

The routine procedure followed at present for estimating the filling and emptying phenomena is to make the usual postero-anterior, lateral and vertical skiagraphs with the vertical film and the horizontal X-ray beam, as described under "Radiography." A single complementary exposure is made on the third day, as near the termination of the seventy-two hour interval as possible. Which of the initial positions is to be repeated for this final film is left somewhat to the discretion of the individual observer. A practical rule is to determine which of the initial films permits of the readiest topographical interpretation and to repeat this position for the seventy-two hour film. The vertical position will usually be found to be the one of choice. In

Fig. 93 Delayed emptying I. First film shows antra and sphenoids filling; ethmoids failing to fill. It is to be expected that the cells contiguous to the nonfilling ethmoids will empty slowly.

Fig. 94. Delayed emptying. II. Seventy-two hour film shows retention in right antrum and left sphenoid. It often happens that when certain cells fill while contiguous cells remain empty, those which do fill empty with difficulty; showing obstruction, general, but varying in degree.

this position the overlapping of parts is negligible and small variations in emptying are better detected. If for economy or any other reason, only a single radiogram with opaques is permitted, the author's choice unhesitatingly falls upon this position as the one supplying the most information. (Figs. 91 to 94.)

The patient during the period of investigation is given no instructions further than that he is to refrain from using any special manipulations with regard to his nose. He may blow it if he likes and should continue with his usual occupations. All sprays, irrigations or other treatments are interdicted in the interval.

CHAPTER XVI

SOURCES OF ERROR

PROJECTION OF SHADOWS—INTERPRETATIVE ERRORS—TECHNICAL ERRORS.

Skepticism and indifference to the diagnostic advantages of fluid radiopaques in skiagraphy are usually based upon a brief experience of failures which might have been easily and entirely avoided. These failures in diagnosis can commonly be traced to some unfamiliarity with the mechanics of fluids or to some failure in the observance of a few simple rules of radiographic technic. From a topographical standpoint, one is attempting to visualize the exact definition of the cell cavity and to distinguish it from the bony sinus wall by its shadows. Definite objects under the same conditions of radiation must invariably cast like shadows. Dissimilar objects under varying conditions of radiation may cast similar shadows, so as to be readily confused with one another. If one is to interpret the significance of a shadow he must know the circumstances under which it was cast and the relations of the source of radiation, the opaque body and the film. When fluid opaques are involved it is necessary, in addition, to know the relation of the whole system to the horizontal. He must anticipate and eliminate factors which admit possibilities of error if he is to reason from effect back to cause. What he actually sees in the shadow of an irregular mass is roughly a composite of the parallel planes produced through its extreme dimensions, somewhat enlarged. It is in its simplest form when the surface upon which it is cast, in this case the film, is perpendicular to the central beam of radiation. In this case the shadow is a composite

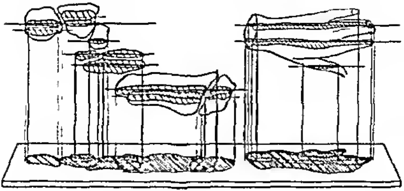


Fig 95. The shadow outline of any opaque body or group of bodies is the composite of all the planes lying perpendicular to the beam of light

of planes parallel to itself. (Fig. 95.) Its dimensions exceed those of the opaque body in direct ratio to their respective distances from the source of radiation.

PROJECTION OF SHADOWS. This brief excursion into elementary physics will serve to explain the difficulties which arise when a three-dimensional object is to be interpreted in terms of its two-dimensional shadow, and to point out the variations which must occur in that shadow with every change in the relationship of its determining factors. The vertical shadow of a vertical cylinder a foot high and an inch wide is a perfect circle, something over an inch in diameter. (Fig. 96.) The horizontal shadow of the same cylinder in the same position is a narrow stripe somewhat over an inch wide and twelve times as long, and yet there are those who undertake to interpret oil shadows in roentgenograms without troubling to ascertain the positions in which they were made!

It will be seen that, topographically, opaque filling indicates —in fact, accentuates—any discrepancies which may exist between the bony wall of a sinus and its actual air cavity. Such discrepancies are termed "filling defects" and may be anything from a slightly thickened membrane to complete

obliteration of the cavity. Filling defects may be suggested where they do not exist by shadows arising through faulty technic.

INTERPRETATIVE ERRORS. The chief diagnostic errors fall into two classes: interpretative and technical. Of the interpretative group, failure to identify cells and to distinguish them from one another is most frequent. This occurs in regions where cells normally overlap, as do the pre-ethmoidal group and the horizontal pneumatization of the frontal, and even more frequently the posterior ethmoid and the sphenoid. Bilateral filling, especially, demands constant comparison of the three positions in order to identify individual cell shadows. Radiography with the horizontal beam minimizes this error. (Chapter XII.) Ethmoids and sphenoids so often encroach upon one another's territory that even films in three positions may leave some reasonable doubt as to their identity. Under such circumstances, if relations and measurements do not help, the question may have to be decided through some individual peculiarity of the cell. If, by good fortune, a pneumatization of the ptery-

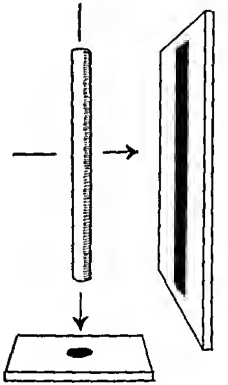


Fig. 96. Dissimilarity of shadows of a cylinder, cast by vertical and horizontal beams.

goid process is demonstrable, the cavity is of course at once identified as the sphenoid. Pneumatizations in this region are not rare (about 20 per cent). They are described elsewhere.

Problems of identity between the two sphenoids arising as the result of a great disparity in size and the consequent partial envelopment of the one by the other, may be solved by the comparison of the three views. (See Case 7, Chapter XX.) Occasionally one sphenoid may pass behind and completely surround its neighbor, the shadows overlapping in all of the three positions, the smaller cell so near the midline as to make lateralization difficult. In this case the decision must rest upon unilateral opaque injection, by cannula or trocar. A small sphenoid not centrally placed may readily be mistaken for a posterior ethmoid cell, and so far as the cell itself is concerned its classification has little clinical significance. From a surgical standpoint, however, it is important to know whether the space behind it communicates with the opposite side, which it will do if it is a ramification of the opposite cell, but which it will not do if it is a sphenoid covered by what proves to be a posterior ethmoid.

Fig 97. Injection into a polyp.

The technical questions of partial filling and the horizontal beam and their importance in eliminating errors have already been considered.

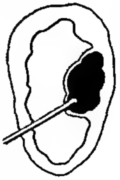


Fig 98. Injection beneath the surface of the membrane.

TECHNICAL ERRORS. It sometimes occurs, in introducing fluids by puncture,

that the needle may penetrate a polyp and that the injection of oil may be made into the tissues of the polyp instead of the sinus cavity, or the needle may go beyond the cavity, penetrate the edematous mucosa of the opposite side and deposit its oil beneath it. The resulting radiographs in either case will be misleading.

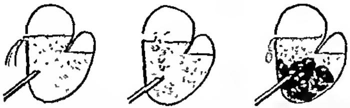


Fig. 99. Effect of washing and blowing out a sinus before introducing oil. First water is introduced until it overflows at the ostium. *Second, air which follows it bubbles up through* it and escapes without removing the water. Last, oil is introduced which, in contact with the water, assumes grotesque shapes.

Washing the sinus immediately before introducing an oil is not to be recommended, even though this is followed by blowing air through it. Water remaining in the cell alters the oil shadow by causing the oil to assume globular shapes instead of adapting itself accurately to the cell wall. It may cling in places to the wall and cast grotesque shadows which are without meaning. Air blown into a cavity after washing does not necessarily remove the fluid. It bubbles up through the fluid and escapes through the ostium. Only when the ostium is at the bottom is the sinus effectively emptied. If it has been necessary to wash the sinus, at least twenty-four hours should be allowed to elapse before the oil is introduced.

Errors may arise in the identification of cells in seventy-two hour films through failure to duplicate exactly the positions of the initial exposures. With a cell only partially filled, slight

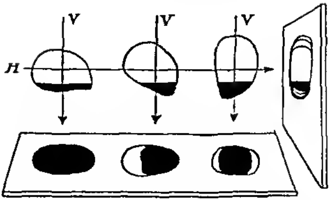
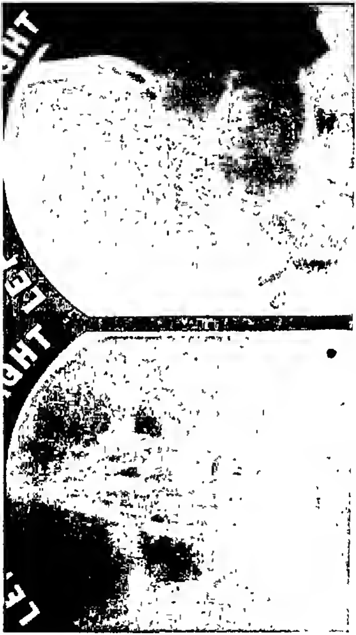


Fig. 100. Variations in oil shadows caused by minor changes in position of the sinuses, with the vertical beam. With the horizontal beam these are minimized

variations in the head position may cause pronounced variations in the shadow of the oil pool as the latter adapts itself to the dependent portion of the sinus. This is especially true if the shadow has been cast by a vertical beam, for the reason that a small amount of oil confined to a depression in the floor of a sinus produces a small shadow, whereas the same amount of oil spread out on a neighboring plateau by a slight change in the head position may cause the sinus to appear almost completely filled. As the horizontal beam shadow silhouettes the depth of the pool instead of its surface, the variations are small and the relations of oil shadow to bone shadow are much more likely to approximate the true condition. (Fig. 100.)

It may be suggested that in cases of atrophy in which the ostia are extremely large, oil may drain from a sinus after filling and before the patient reaches the radiologist. This condition is not likely to be mistaken for failure to fill, as the most casual inspection of the nose distinguishes the two. Such precipitate emptying occurs only in extreme atrophy or following operation.

Fig. 101. Film kindly supplied by Dr. Fraser of his lateral position with the vertical beam This outlines the borders of each group of cells but in the author's opinion is far less valuable than the horizontal beam shadow for diagnosis. Note, for instance, the irregular diminishing shadow at the floor and back of the antrum. It should be understood that Fraser does not employ this view for the estimation of membrane thickening.



Figs. 102 and 103. Case of chronic maxillary sinusitis. Films made without a contrast medium. The radiologist's report read: "Both sinuses are clear. No visible evidence of pathology."

Figs. 104 and 105. The same patient as the preceding. Films made shortly afterwards by the same radiologist, but this time with a contrast medium, show large filling defects in the right antrum. Convex shadows of masses lying anteriorly and posteriorly outlined by vertical oil shadow in lateral view. Globular mass hanging from top and thickening of the membrane are shown in the anteroposterior view. The left antrum fails altogether to fill.

CHAPTER XVII

DISPLACEMENT IN CHILDREN

DEVELOPMENT OF SINUSES AT VARIOUS AGES—PRECAUTIONS—PRACTICAL SUGGESTIONS.

Displacement in children presents no especial technical difficulties beyond the usual one of gaining the child's confidence. His coöperation, while of course desirable, is not essential. Satisfactory films have been made of infants one year of age. They have the same diagnostic value as those of adults, and no harmful effects following either diagnostic or therapeutic fillings have been reported.

Radiopaques often serve to outline cavities in children which simple X-ray films do not reveal, owing to the relative delicacy of some of the bony outlines of the child's skull, combined with the relative density of unpneumatized bone and the increased *difficulty* of *immobilizing* the head during exposure.

Children's sinuses fill comparatively easily, due to the patency of their ostia and the comparatively large size of the latter. For the same reasons, the emptying time is much reduced —sometimes to twenty-four hours.

One must familiarize himself with the development of each sinus at various ages and not expect sinuses to fill which do not exist.

Development of Sinuses at Various Ages. The most constantly and uniformly developed of the sinuses in the child is the ethmoid. It is relatively larger than the others in small children, and even in infants from 18 months to two years old the ethmoidal filling is comparable to that of the

Fig. 106. Radiogram of a child three years old. The oil was introduced by displacement

adult in extent and distribution, though naturally smaller in total amount. Agger cells can be outlined even in small children.

The maxillary antrum in children under one year does not extend beneath the orbit, or at least beneath the infraorbital canal. While still a narrow cavity, it is easily demonstrated and identified in the postero-anterior films. This slit develops rather steadily and uniformly until about the eighth year, when it assumes the adult position and proportions, although the adult size is not attained until maturity.

The frontal sinus is seldom evident before the third year. From that time on until the adult stage it may be anything from the size of a pea to the extensive proportions described in the section under Anatomy.

Fig. 107. Radiogram of a child six years old.

The sphenoidal sinus begins as a pouch of the mucosa, on the face of the body of the sphenoid bone, and is capable of filling with opaque oils even at this stage. Schaeffer[151] points out that the sphenoidal sinus "is early of importance clinically, and that by the second or third year it has assumed proportions sufficiently large to become the seat of pathologic processes and to retain infectious material in its cavity."

Precautions and Practical Suggestions It is well, if the child is old enough, to gain its confidence in various ways. The terror of the suction apparatus can usually be overcome by letting him feel the suction on his finger and allowing him to play with the end of the tube. Applying it to his nose then becomes part of the game, and if "coconut-cake" or some similar word is substituted for the pointless and unamusing

Fig. 108. Radiogram of a child six years old.

"K" he readily closes his pharynx and the whole performance is completed before he tires of the sport.

Children who are too young for this type of approach are swathed in a sheet and laid in the usual position. With the head thus extended, the pharynx closes naturally, especially if the child cries, and there is no real difficulty in procuring a vacuum when the tip is applied.

One precaution is imperative in young children: they should be gagged before introducing the oil. The mouth is held open by means of any of the usual gags to prevent the child's snorting the oil from his nose before suction can be made. One such experience will fix this precaution permanently in the mind of the operator.

A word as to treatment: This finds its chief application in those copiously and persistently discharging noses which

fail to respond to the usual drops and lotions, and avoids many a puncture.

From two to eight mils. (according to age) of the .5 per cent ephedrin or, better, .25% 2-amino-heptane sulphate in physiologic salt solution is introduced by displacement every other day. The first few treatments are commonly followed by a discharge even more profuse than usual, if that is possible, after which it quickly diminishes and soon ceases altogether. This is the rule if the condition is amenable to treatment by this method. Infections of long standing sometimes respond very quickly and are completely eradicated after eight to a dozen such irrigations. Cases which fail to respond to any degree in this short time are unlikely to respond at all.

CHAPTER XVIII

THE OBSERVATION OF ALLERGIC CHANGES IN THE SINUSES BY MEANS OF RADIOPAQUES

CHARACTERISTICS OF ALLERGIC MEMBRANES—THEIR DENSITY — DISTRIBUTION — RAPIDITY OF REACTION—SWELLING DUE TO RADIOPAQUES—ALLERGY AND HYPERPLASIA—SHADOW CHARACTERISTICS.

The subject of allergy, which has been so thoroughly investigated and is still so imperfectly understood, is often of special concern to the laryngologist. He is often obliged to decide not only whether the patient is an allergic subject, but granted that he is an allergic subject, whether a given nasal disorder is the result of it, or whether the usual infection lies at the bottom.

Today the picture of vasomotor rhinitis has become a familiar one.

In view of the swelling, laxity and edema of the nasal mucosa, as a result of the individual's sensitivity to foreign substances, it is scarcely surprising that the sinus mucosa should respond in a similar manner.

However, as no erectile tissue exists in the sinuses, and in view of the relative thinness of the mucosa as compared to that of the nose, the extent and rapidity with which it swells during an allergic attack are astonishing.

This reaction has been noted in all the sinuses to some extent, and while it has appeared most strikingly in the antrum, it is more than likely that the topographical situation accounts for this. Here again, the antrum, by virtue of its accessibility

to filling and to observation, has been more thoroughly studied than have the other sinuses.

It is very difficult to fill sinuses by displacement while the patient is under the influence of even a mild allergic attack. In fact, this is practically the only situation which prevents any oil whatever from entering any of the sin uses by displacement. While this complete failure to fill may hardly be advanced as pathognomonic of allergy, it is so striking as to be highly suggestive. Small amounts of fluid may be made to enter, if required, by resorting to preliminary shrinking.

SUDDEN REACTIONS. The lining membrane of the maxillary sinus can, under the influence of an allergic reaction, increase in thickness from a fraction of a millimeter to one centimeter or more overnight.

The appearance of polyps, of diffuse edema, and of similar filling defects commonly noted in radiographs of the antrum has long been regarded as the result of chronic inflammation, and in many quarters is considered sufficient evidence of hyperplasia to justify more or less radical operative interference.

It has been shown,[167 168] however, that a membrane may swell to several times its normal thickness between the time of the original injection and that of the seventy-two hour plate.

SWELLING DUE TO OPAQUE OILS. The extent, the prevalence and the rapidity of this reaction in allergic individuals seem to depend somewhat upon the radiopaque employed. This observation is based upon a series of cases studied over a period of four years. During the first three years a single radiopaque was employed, which was diluted one-half with olive oil. From this series, only an occasional instance of rapid thickening was encountered. Later a new radiopaque, then first appearing on the market, became the medium of choice. This oil, a bromin compound of certain esters of the acids of

olive oil, was used undiluted. In the new series about one in five patients shows a demonstrable thickening of the membrane between the original exposure and the seventy-two hour plate. This was at first thought to be due to the possible irritating action of the bromin on the sinus membrane, but in the light of later experience it is now regarded to be allergic.

The maxillary mucosa has been observed to swell under an allergic attack to many times its normal thickness; in fact, to a practical obliteration of the sinus cavity in a very few hours. In this condition, it presents every appearance of polyposis and the boggy early stages of hypertrophy and hyperplasia. (Figs. 110 and 112.)

It casts shadows which are pale and of uneven density, and have the multiple convexities characteristic of polyps. These shadows may disappear rapidly, as the edema subsides as quickly as it came.

The folly of an operation based upon such evidence alone is obvious. Confirmatory films should be made at a later date, when the patient is free from allergic symptoms.

It has been observed that a sudden allergic reaction coincidental to a general attack may be confined to a single sinus without affecting its fellow on the opposite side, or any of its neighbors, or occasioning any nasal obstruction.

Allergic Swelling and True Hyperplasia. The fact that an apparently normal membrane in an allergic individual may undergo these rapid and extreme variations should not lead one to the hasty conclusion that any thickened mucosa in an allergic subject must be of this nature. True hyperplasias naturally exist in allergic individuals. Whether or not exenterating operations in such cases are productive of any relief is a moot question and aside from this subject. The two conditions should at least be distinguished.

Fig 109. Lateral film made immediately after filling by displacement The large amount of fluid in the right antrum had been introduced through a trocar a few days before Note apposition of oil to cell wall throughout This and the three subsequent plates are from Case 12, page 221

Fig. 110. Lateral film made seventy-two hours after Fig. 109 and twelve hours after acute asthmatic attack. Note the extreme thickening of the mucosa.

Fig. 111. Postero-anterior view of Fig. 109. Note again the thin membrane in the antrum and also in the sphenoid and ethmoid cells above.

Fig. 112. Postero-anterior view of Fig. 110. Note extreme thickening of antral mucosa while that of ethmoid and sphenoid remains unchanged.

Fig. 113. Attempted filling during the active stage of a case of "intrinsic" allergy. A few drops of oil cling to the rostrum of the sphenoid and to the lateral pharyngeal wall. No oil has entered any sinus.

Fig. 114. The same case fourteen days later, and now symptom free. Even now the oil has penetrated only the sphenoids which still show convex filling defects. There is a small amount also in the left anterior ethmoid.

SHADOW CHARACTERISTICS. There are certain characteristics in which the two shadows differ. The allergic membrane, as has been said, casts a relatively pale shadow due to its loose texture and fluid content. This shadow is of uneven density and its margins are the convex shadows of multiple globules, which do not parallel the bone shadows.

True hyperplasias, on the other hand, usually, though not always, cast even shadows, denser than the others and uniform in width—that is, they conform in general to the contours of the bony walls. (See Fig. 83.)

Hansel[77, 81] has identified histologically in individual cases the two types of membrane casting the shadows described.

Stout[195] has published the comparative results of antrum observations by various methods in asthmatic subjects and summarized them. Aside from the question of allergy and merely as a commentary upon the usefulness of the radiopaque in demonstrating disease conditions, it is significant that of the fifteen antra in his series which were opened and subjected to direct inspection five were doubtful and one frankly negative on simple X-ray examination, whereas with the radiopaque not one among the fifteen was even doubtful. The old contention that the perfect radiologist could have detected the trouble from the simple X-ray film may be admissible even here, but it is not convincing.

Remote allergic manifestations have sometimes followed the use of radiopaque oils in individuals who were sensitive to *the vegetable oils themselves. Thus, a severe urticaria of hands* and feet occurred in a medical student following the introduction of lipiodol into the sinuses by displacement. This student's skin reacted violently to a drop of poppy-seed oil applied by the cut method.

CHAPTER XIX

AEROSINUSITIS AND AEROTITIS

The war brought into prominence two conditions resulting from high altitude flying, namely aero-sinusitis and aerotitis, or as they are known in England, "barotrauma". These disturbances were recognized before the war, but they received little attention since the requirements of civilian flying at that time demanded neither very high altitudes nor sudden changes of altitude.

Under combat conditions, however, calling for substratosphere travel and reconnaissance and especially such maneuvers as dive bombing, these disturbances in the ears and sinuses became more frequent and more disabling and demanded investigation. Exhaustive research was done in and out of the armed forces and detailed reports were made by Campbell[25] and others,[60, 170] to which the reader is referred.

The mechanical factors in both aero-sinusitis and aerotitis are substantically the same. The symptoms occur when the sinus ostia or the eustachian tubes for any reason do not permit the free passage of air. As the subject leaves the ground in flying, atmospheric pressure gradually decreases. At 18,000 feet it is reduced by one half. The air in the middle ear and the sinuses escapes and the pressure in these cavities becomes that of the surrounding atmosphere. On descending the reverse takes place. If the descent is great, and especially if it is sudden as in diving, the ostia and the tubes may under suitable conditions act as flap valves and prevent the return of

RESULTS OF TREATMENT*

TOTAL CASES	CASES STAGE I	CASES STAGE II	CASES STAGE III	TOTAL TIME LOST FROM FLYING (AVERAGE)
METHOD: VASOCONSTRICTOR, POLITZER BAG, and/or CATHETERIZATION				
	28			10 Days
48		18		12 Days
			2	15 Days
METHOD: VASOCONSTRICTORS AND SEDATIVES ALONE				
	8			12 Days
12		3		16 Days
			1	16 Days
METHOD: DISPLACEMENT—WITHIN 4 TO 6 HOURS AFTER ONSET				
	58			2 Days
68		8		3 Days
			2	14 Days
METHOD: DISPLACEMENT—WITHIN 30 MINUTES AFTER ONSET				
	46			4 Hours
59		8		24 Hours
			5	14 Days

Stage I.—Marked retraction of ear drum with moderate, deep-seated pain in ear; moderate capillary injection of drum; bubbles of serum scattered over inner surface of ear drum.

Stage II.—Actual demonstrable fluid level in middle ear; marked generalized capillary injection of the ear drum.

Stage III.—Fluid level in middle ear obscured by marked reddening of ear drum; extreme pain relieved only by opiates. (In all cases: (a) Weber fork test lateralized to involved ear. (b) Marked loss of hearing acuity for low tones.)

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*From Wisehart.

CHAPTER XX

CASE RECORDS

The following case records are presented as typical working examples of the abstractions embodied in the foregoing chapters. Each one is chosen because it demonstrates some application of the principle of displacement in a concrete way. They represent neither the most difficult cases nor the simplest, but a fair average of those encountered routinely in practice. Some cases are presented as examples of treatment; in these much stress has not been laid upon details of diagnosis. In others, which demonstrate some diagnostic point, the treatment has been emphasized only as it bears upon diagnosis. For the sake of brevity, all details not pertinent to the case have been omitted.

Among the group are instances in which the diagnosis could have been made, and was, without roentgenographic aid. They illustrate the reliability of drainage estimation as an index to disease, demonstrated at operation.

CASE 1. CHRONIC POSTERIOR SINUSITIS WITH PROTRACTED HEADACHE

No. 3196. Female, aged 23, was referred by an internist to determine the source of headache and postnasal dripping dating from a streptococcic infection of the throat four years previously. The headache was usually confined to the vertex and the occiput but sometimes became general. There was general lassitude and some giddiness, and exercise caused the

Fig. 115. Case I.

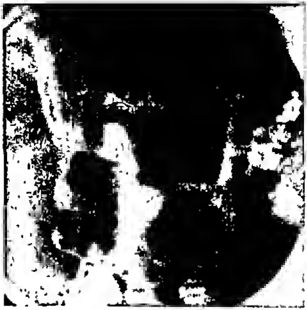


Fig. 116. Case I. Note the unusual size of the posterior cells and the thinness of their walls.

Fig. 117. Case I. Vertical position, first film

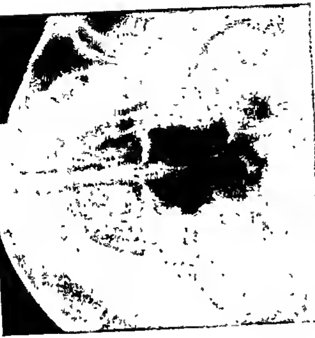


Fig. 118. Case I. Vertical view, seventy-two hour film Note example of normal emptying in spite of the unusual size of the sinuses

ears to feel stopped and the vision to blur. There was occasional irregular heart action and some intestinal trouble.

The patient had had a submucous resection of the septum one year previously and a tonsillectomy shortly before that. There was a history of influenza with mastoiditis in childhood which subsided without operation. The nasal examination showed a generally flushed membrane, which was fairly thick and somewhat uneven. The posterior nasal membranes were irregularly mottled and the pharyngeal lymph tissue was unusually prominent. There was a small adhesion between the posterior end of the left middle turbinate and the side of the septum. X-ray examination with opaque oils by displacement revealed unusually large sphenoid and posterior ethmoid cells. The drainage was only moderately impeded, but the retention was sufficiently definite to suggest irrigation. Seven irrigations with .5 per cent ephedrin solution, covering a period of one month, resulted in complete and permanent relief from symptoms.

Comment: The posterior ethmoid and the sphenoid cells were characterized chiefly by their size and the thinness of their walls. (Fig. 116.) The lateral view illustrates well the two levels of the floor of the maxillary sinuses.

Case 2. Chronic Posterior Ethmoiditis With Severe Headache

(W. U. Disp.). Female, aged 39, waitress, complained of daily incapacitating headaches, sometimes frontal, but generally occipital, and usually accompanied by nausea and vomiting. The symptoms were of such severity that she had had to give up her work. Had been treated in the dispensary for five months with little relief. The general findings, including

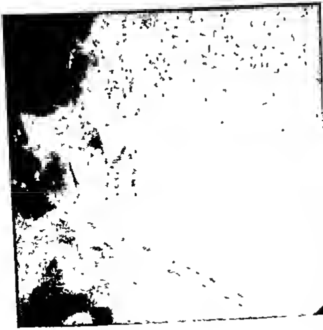


Fig. 119. Case 2. Lateral view in the inverted position showing normal filling of posterior ethmoid while the sphenoid remains empty

Fig. 120. Case 2. Lateral view in the inverted position after four irrigations with normal saline. Both posterior ethmoids and sphenoids now show normal filling.

the Wassermann reaction, were negative. The original X-ray report without radiopaques was: Sinuses "indeterminate."

The nasal picture was patently that of chronic posterior sinus disease. Cocainization of the nasal ganglion gave only transient relief. Injection by displacement succeeded in filling the posterior ethmoids to a normal level, but the sphenoids failed completely to fill. (Fig. 119.) This was before the advent of ephedrin and irrigations with physiological salt solution were instituted, the region of the sphenoid ostia having first been shrunken with cocain and adrenalin. Vomiting ceased after the first injection and headaches after the fourth. A second attempt to fill the cells with radiopaques at this time resulted *in the filling of both the sphenoids and the posterior ethmoids.* (Fig. 120.) The patient had remained free from headaches when discharged five months after the termination of treatment.

Comment: This is a striking example of the relief of symptoms together with the demonstration of subsequent patency of an ostium originally found obstructed.

X-ray examination without radiopaques had failed to disclose the trouble.

Case 3. Hyperplastic Rhinitis With Protracted Severe Headache

No. 2339. Female, aged 35, stenographer, complained of excruciating pain in the right side of the face, radiating to the back of the head and neck; a swelling around the right eye sometimes accompanied the pain. This condition began about eight years ago. Since that time the patient had had an annoying postnasal discharge and frequent colds. She had also undergone a curettage and an appendectomy six years, and a submucous resection of the septum one and one-half years previously. These had given her no relief. Recently, the headaches had become incapacitating.

Fig. 121. Case 3. Average filling of the ethmoids, subnormal filling of the antra and sphenoids. Note oil retention in the region of the anterior clinoid process

Examination revealed pain to pressure on the floor of the right frontal sinus but no sensitiveness of the supraorbital nerve on that side. The left was not sensitive. The nasal membrane was generally hyperplastic. A submucous resection had been performed, and there were two small anterior perforations and a soft ridge along the floor of the right side. The inferior turbinate on the left side had been closely amputated. As the patient had no knowledge of this, it is assumed that it was done at the time of the submucous resection. On the right side

the membrane was hyperplastic, very irregular, thick and white. The posterior ends of the middle turbinates were hyperplastic; the face of the sphenoid was pale and dull.

X-ray examination with radiopaques by displacement showed a fairly even distribution of the oil to all the sinuses except the sphenoid, in which the filling was subnormal and showed retention in an anterior clinoid process. (Fig. 121.) This was before the seventy-two hour film to determine drainage had been adopted, and no drainage observation was made. In view of the constant acrid postnasal secretion and the ease with which oil could be introduced into the sinuses, the routine instillation of ephedrin solution by displacement was instituted. Eight irrigations were administered, extending over a period of three weeks. At the end of that time the pain had entirely disappeared and the secretion was much reduced. The patient was then seen at monthly intervals to determine progress. After a few months she was lost sight of and did not return until two years later. She had been entirely free from headaches in the interval and had now developed a return of the pain. There was at this time no secretion and the over-ventilation of the right side had apparently resulted in irritation of the face of the sphenoid in the neighborhood of the right nasal ganglion. A single cocainization of this ganglion was followed by freedom from pain for six days, when a second headache occurred which was promptly and permanently controlled through another cocainization of the ganglion.

Comment: This is one of a series of cases in which headaches of long duration (years) have responded to a few irrigations. These headaches are apparently maintained by a constant irritation of the nasal ganglion or its branches through acrid or inspissated secretions. They are probably of the same type as those which respond to a single injection of some oily radiopaque introduced for diagnosis. (See Case 8.)

Case 4. Pansinusitis With Protracted Severe Headache

No. 3042. Male, aged 39, engineer, was referred by an internist for sinus examination; the chief complaint was severe bilateral frontal and temporal headache, and copious purulent nasal secretion, both of many years' duration.

The nasal mucosa was irregularly hyperplastic with some areas of atrophy. There was always a copious drainage of pus from above and below the middle turbinates and frequently crusting along their margins and in the nasopharynx.

X-ray examination with radiopaques by displacement showed only moderate general filling and partial retention in each cell. The membranes were uniformly thickened to about two or three millimeters.

In view of the extent of the involvement, the chronicity of the disease and the beginning atrophy, surgery here would have been certain of failure. A series of six irrigations with .5 per cent ephedrin solution relieved the patient of all pain and resulted in a general improvement of his physical condition and his capacity for work. At intervals of one month at the beginning, later two months or more, the symptoms returned; but only occasionally with their original severity. These always followed long, dusty drives across country and responded to one or two irrigations. The patient has gained ten pounds and has retained them. His present physical condition is excellent and he is rarely incapacitated.

Comment: This is a typical pansinusitis in which it is so difficult to obtain results by any treatment. It is the type in which one operation succeeds another only to result eventually in a roomy, crust covered, uncomfortable nose in which the pathologic processes have been aggravated instead of allayed. Under the irrigations, which are not frequent, the patient

Fig. 122 Case 4 Postero-anterior view showing only moderate general filling. The membranes are uniformly thickened to about two or three millimeters.

Fig. 123. Case 4 Postero-anterior view, seventy-two hour film, showing partial retention in each cell

remains free from headache and in good general health. This patient travels extensively and has from time to time been referred to rhinologists in other cities for irrigation. On one of these occasions the irrigation was followed by an argyrol nasal tampon, which increased the headache so as to incapacitate the patient for some time. This has not occurred following the simple irrigation without tamponade. The fact that this man, who has undergone various treatments in many places, makes a trip across the state to have his nose irrigated when the symptoms arise indicates that the improvement is not entirely objective.

Case 5. Sinusitis—Headache

No. 2869. Female, aged 24, housewife, complained of postnasal dripping and headaches, usually occipital but often radiating to the frontal region. There was a history of an antrum infection and a severe attack of influenza. Otherwise illnesses had consisted chiefly in frequent attacks of postnasal discharge, with their attendant headaches.

Examination showed the nasal membrane engorged but the passages moderately well open. The right inferior turbinate was congested and showed areas of hyperplasia, apparently the result of chronic infectious secretion from the middle meatus. The nasopharynx and pharynx were congested, and there were thin streaks of pus to be seen on the posterior surface of the palate and along the lateral lymphoid bands of the pharynx, which were inflamed but not much thickened. The tonsils had been cleanly removed.

X-ray examination with radiopaques showed fairly general filling, with the exception of the left posterior ethmoid cells (Figs. 124 and 125), and delayed emptying in the remainder of the ethmoids and sphenoids. The maxillary sinuses emptied normally. (Fig. 125.) After six irrigations with .5 per cent

Fig. 124. Case 5. Lateral view showing general filling and extensive pneumatization of the posterior ethmoid and sphenoid cells with thin walls. This patient is a sister of the one described in Case 1.

Fig. 125. Case 5. Vertical view. In this position it can be seen that the posterior ethmoid cell on the right filled badly, that on the left not at all.

Fig. 126. Case 5. Lateral view, seventy-two hour film showing retention in the ethmoids and sphenoids. Normal emptying in the antra.

ephedrin solution the discharge was controlled and headaches ceased. The patient was discharged in September. There was only one exacerbation the following winter, occurring in January, and necessitating three irrigations. The following fall, twelve months after the original irrigation, the patient again complained of postnasal dripping, and a large amount of pus appeared during the displacement maneuver. This attack was again controlled by three irrigations, two days apart. There were only two minor colds during the succeeding winter, which was a bad one, and the last interval, which extends to the present writing, exceeds nine months.

Comment: This is another case of chronic sinus disease which can probably not be permanently cured by any means, because the patient is susceptible to infections indigenous to

the Mississippi Valley. However, the attacks have been reduced to three in two years, which is a high average of health, not only for the patient but for the community in which she lives.

Case 6. Chronic Posterior Sinusitis With Protracted Headaches

No. 2967. Female, aged 43, no occupation. This patient complained of left frontal, temporal and occipital headaches, radiating to neck and shoulder. The headaches had begun twelve years ago but had become more severe and more frequent in the two years preceding the examination. There was some headache almost continuously, worse in the morning and accompanying fatigue. There were severe attacks every three to four weeks. The natural menopause had occurred five years previously and had had no effect upon the headaches. There was no history of nasal discharge, but of much postnasal secretion. The digestive tract and the thyroid were negative. The tonsils had been removed eight years previously, and five teeth had been removed since that time. There had been no nasal operations. The patient led an active life and was under much social strain. One year previously she had had an albuminuria, which had since disappeared. The patient had had much nasal attention and various treatments had been instituted for the relief of her headache.

X-rays taken a year previous to the present examination showed a doubtful cloudiness of the sphenoids. On first examination, the nasal membrane was normal in color and moisture. The margins of the middle turbinates, right and left, were moderately thickened. The septum was deviated somewhat to the right superiorly, without much obstruction. The tonsils had been cleanly removed but the pharyngeal mucosa was chronically thickened. The posterior ends of the middle turbinates

were hypertrophied. The face of the sphenoid was visible on the right side after shrinking and the ostium could be seen. The membrane here was palpably thickened. Nasopharyngoscopic examination revealed a general, pronounced congestion posteriorly, especially on the face of the left sphenoid, even after shrinking. The right side was relatively quiescent but showed thickenings and the prominent vessels characteristic of an old infection. The headache responded temporarily to cocainization of the nasal ganglion.

The radiopaque filling by displacement was abundant throughout (Figs. 84, 86, 88), indicating patency of the ostia, but the mucosa was thickened. After seventy-two hours the right posterior ethmoid and the sphenoids still retained oil, although no trace remained in the other sinuses. (Figs. 85, 87, 89.) Irrigations with the ephedrin solution failed to improve the situation and a bilateral sphenoid-ethmoid operation was resorted to. This was followed by complete relief from symptoms and the patient was discharged one month later as cured. This occurred two years previous to the present writing, and it is assumed that the relief has continued, as no word to the contrary has been received.

Comment: This is a characteristic instance of failure on the part of the diseased cells to empty themselves, while their unaffected neighbors are free of the oil in seventy-two hours.

CASE 7. RIGHT-SIDED HEADACHE HAVING ITS ORIGIN IN THE LEFT SPHENOID*

Female, aged 59, housewife, complained of right supraorbital headache radiating toward the right occiput; some sneezing but no obstruction. Two years before, this patient had undergone a right sphenoid-ethmoid exenteration and a

*This patient was observed with Dr. James B. Costen, who furnished the illustrations and kindly permitted this publication.

Fig. 127. Case 7. Postero-anterior view, injection per cannulam of right sphenoid through operative opening.

Fig. 128. Case 7. Lateral view of previous filling in the inverted position, showing the right sphenoid anteriorly placed.

number of polyps were removed. No relief from the headache was obtained. Examination showed complete exenteration of all the posterior cells on the right side. The shallowness of the right sphenoid led Dr. Costen to suspect that perhaps it was in reality a posterior ethmoid cell and that the sphenoid lay behind it. Simple X-ray examination failed to throw any light upon the matter.

Injection of the right sphenoid per cannulam yielded the shadows reproduced in Figs. 127 and 128. The first of these showed nothing more than a pneumatized pterygoid process. The second, however, suggested that the exenterated cell did not account for the whole body of the sphenoid on that side.

The oil was accordingly drained from the sinus, and the left sphenoid was injected through its normal opening. This revealed the true state of affairs. The sphenoid shadow (Fig. 129), after this unilateral left-sided injection, extended the whole width of the sphenoid. That this was not due to any dehiscence in the septum causing the overflow into the right sphenoid was demonstrated by the characteristic dissimilarity of the two shadows, namely, the pterygoid outline in the first instance and the lack of it in the second. Fig. 130, the inverted position of the foregoing, showed that the left sphenoid occupied the posterior half of the body of the bone. Fig. 131 shows in a lateral view the curved cannula still in position in the left sphenoid and the straight probe against the posterior wall of the shallow right sphenoid. The thickened membrane is well demonstrated in this view.

The left sphenoid was exenterated, which was followed by complete relief of the right-sided headache.[23]

Comment: This illustrates an anomalous relation of the sphenoids, described in Chapter XII, in which a large left-

Fig. 129 Case 7 Postero-anterior view, injection of radiopaque into the left sphenoid through ostium after evacuating the right The outlines of the unfilled pterygoid process on the right are vaguely seen. Note that the left sphenoid here injected extends across the entire body of the sphenoid.

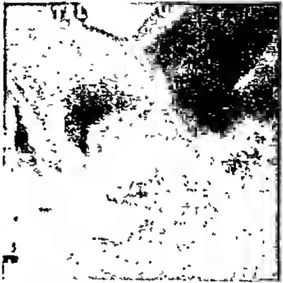


Fig. 130 Case 7. Lateral view of previous filling in inverted position, showing left sphenoid posteriorly placed.

Fig. 131. Case 7. Lateral view Curved cannula in left sphenoid immediately after filling shows thickened membrane; straight probe against posterior wall of empty, anteriorly placed right sphenoid.

sided cell extended behind and around a small right-sided one. In this case, the left sphenoid produced a right-sided headache. Without radiopaque the topography could not have been demonstrated by simple radiography, as the anteriorly lying sphenoid was not particularly small but extended far into the pterygoid process.

Case 8. Headache Relieved by Oil Injection for Diagnosis

Adult, male, complained of general headaches of six or seven years' duration. These lasted at first for a few hours and recurred every two or three weeks. They gradually became more frequent; began in the morning and lasted all day; they also increased in severity. About four weeks previous to

the examination the headaches became very intense and lasted day and night. Cold air inspired at night caused pain, which was somewhat relieved when warm air was breathed. On October 27, 1926, the patient had a general instillation with lipiodol for diagnosis. The pain ceased practically at once; recurrences became less frequent and progressively less severe. On November 16, 1926, he had no further pain and was not conscious of his head.

Comment: The foregoing sketch is set down as it was brought to my attention by Dr. Amedee Granger. Since that time other cases have been observed in which headaches were relieved by the single diagnostic administration of a halogenated oil. The effect in these eases was probably due to the lubricating quality of the oily principle and not to any specific action of the oil or its halogen component, as similar results were later obtained in isolated cases by the instillation of simple liquid petrolatum (light). It is noteworthy that these headaches, which had been frequent and protracted, were relieved for long periods of time following the intromission of the lubricant.

Case 9. Posterior Ethmoiditis

No. 3333. Female, aged 50, no occupation. This patient was referred by an internist and complained of general asthenia and a bad taste in her mouth; both of three or four years' duration. At first these occurred only at intervals, but lately she was in a state of constant fatigue and much annoyed by the bitter taste. Her general health had always been excellent, and with the exception of typhoid fever at the age of 16 and three operations, one a tonsillectomy, ten years ago, the personal history was unimportant. The internist's examination, including urinalysis, was negative.

Fig. 132. Case 9. Lateral view showing general filling and slight thickening of the right maxillary mucosa.

There was some tenderness over the floors of the frontal sinuses, but none over the supraorbital nerves. The nasal chambers were narrow and the mucosa slightly congested. The septum was straight, and there was a scant sticky mucopurulent secretion on the floors of both nasal chambers but none elsewhere. The turbinates were pale with fairly prominent vessels. The posterior margin of the septum was thin and not inflamed, but there was pronounced congestion of the nasopharynx and the pharyngeal lymph nodes and vessels were prominent. The epiglottis was inflamed, as were the posterior commissure and the arytenoid region of the larynx; all suggestive of posterior drainage. Transillumination was negative.

General filling with brominized oil by displacement showed a fairly even distribution through all cells. The membranes of the maxillary sinuses showed slight irregular thickening but

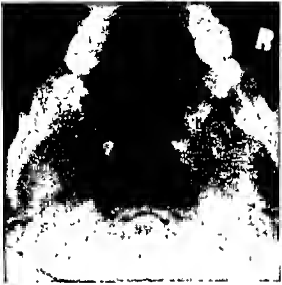


Fig. 133 Case 9. Vertical view showing pronounced retention in the ethmoids.

not to a pronounced extent. (Fig. 132.) The seventy-two hour film showed retention in the ethmoids and traces in the sphenoids. This retention in the posterior ethmoid was so pronounced as to call attention to this group. (Figs. 133 and 134.) General shrinking was resorted to, together with the displacement instillation of a .5 per cent ephedrin solution every other day. No improvement was noted at the end of a week and, as there was not unlimited time at one's disposal owing to the patient's living in another city, partial bilateral middle turbinectomy was resorted to in order to gain space, and the posterior ethmoid cells on both sides were opened. No other cells were touched. The bad taste disappeared at once and the symptoms of lassitude gradually subsided.

There was no further disturbance until nine months later, when there occurred a recurrence of the secretion, which disappeared after two irrigations.

Fig. 134. Case 9. Lateral view accentuating the retention in the ethmoid cells.

Comment: The retention in this case being so definitely confined to the ethmoid cells prompted the opening of these cells alone, and the procedure has been justified by the results which had, at the time of writing, endured for two years. The bad taste has not recurred, and the patient's vitality remains at par.

Case 10. General Nasal Infection in a Child

No. 3721. Male, aged 4, was referred by a pediatrician with the history of a chronic nasal infection, which had been present most of his life. Aside from a severe throat infection, two years ago, there had been no serious illness. The child's general health had remained good but he became fatigued easily. His adenoids had been cleanly removed a year and a half before this examination.

The nasal mucosa was red and swollen throughout and the nose was filled with copious mucopurulent secretion; apparently a pansinusitis. After two days' preliminary treatment with ephedrin followed by argyrol, irrigations by displacement were instituted. After a series of eight irrigations, covering a period of one month, no pus was to be seen. At the present writing, fifteen months have elapsed and there has been no recurrence of the nasal discharge.

Comment: This is an example of a chronic general nasal infection which responded well to persistent drainage with astringents. This child, a robust, active boy of four, offered no objection to the irrigation, which was easily carried out.

Case 11. Pansinusitis in a Child

No. 3703. Male, aged 7½, schoolboy. This patient was brought for the relief of copious bilateral nasal discharge, which had begun as an acute coryza six months previously. He had been seen by a rhinologist in another city, who diagnosed the condition empyema of the left ethmoid and operated upon it, apparently successfully. Two months later, however, during an attack of scarlet fever, the nose had begun to discharge again, which it continued to do in spite of all treatment. From that time until the date of the present examination, a period of three months, there had been no progress in the nasal condition. The boy had always been susceptible to infection, having been rachitic in infancy. Beside the scarlet fever mentioned above, he had experienced in his short life pertussis, pneumonia and meningitis [?]. Tonsils and adenoids had been removed at the age of five.

At the time when the X-ray examination was made, the nasal membrane was chronically thickened, and both fossæ were filled with thick, purulent secretion, which the boy expelled with difficulty owing to the extreme swelling. There

were excoriations about the left nostril. The condition was quite apparently a pansinusitis. X-ray examination verified this diagnosis. As no oil could be made to enter the sinuses, the roentgenograms are not reproduced here. However, following persistent shrinking, ephedrin could be made to enter the cells and daily displacement irrigations were instituted. The condition was improved after the fourth irrigation, and complete recovery followed the tenth.

Comment: This is an example of the response of a recent widespread infection to drainage with astringents when these can be made to reach the affected areas. It is obvious that in such cases shrinking of the nasal mucosa alone is ineffectual. The introduction of the solutions into the sinuses proper, where they can remain long enough to establish drainage, effects the recovery.

Case 12. Sudden Allergic Reaction

No. 21844. Female, aged 38, a music teacher, was referred by an allergist for sinus examination. She presented the typical syndrome of bronchial asthma. The allergic findings are recorded, as they concern the development which occurred in the examination of the sinuses with radiopaques. Not responding to any skin tests, the patient had been referred to the Department of Otolaryngology for nasal examination. Beyond a moderate pallor and a few eosinophiles in the secretions, the nose had shown nothing; air passages were free and the usually abundant mucus was absent. X-ray examination was negative. For some reason, which I am unable to determine, the right antrum was filled with equal parts of lipiodol and olive oil through a trocar. Bone shadow and oil shadow corresponded perfectly and the sinus was pronounced negative. At this time

a filling by displacement was done, using the same radiopaque. The posterior sinuses and the opposite antrum were also negative. (Figs. 109 and 111.)

During the seventy-two hour period awaiting the second film, the patient was permitted to leave the hospital. She visited a relative, slept on a goose-feather pillow and suffered a severe attack of asthma without nasal symptoms. Films made the following morning (Figs. 110 and 112) showed a membrane approximately a centimeter thick, which had extruded most of the oil, and presented the typical appearance of a polypoid antrum. The other sinuses remained unaffected.

That this was not a reaction to the oil itself may be concluded from the fact that there had been some oil in the affected antrum for five days without change and that the thickening appeared only after the asthmatic attack.

Comment: One is unable to explain the reason for the reaction in this single cell which did not take place in the others. It is believed by allergists that local trauma may set off a reaction, and the trocar puncture at first resorted to in this case may have been responsible here. The fortunate coincidence of the asthmatic attack occurring during a progressive daily radiologic examination of the patient strengthens the evidence that the reaction was purely allergic.

Following is the allergist's record of the case: Mrs. C. M. F., seen September 28, 1929. History of winter colds since 1918, which consisted of mild nasal blocking, nasal discharge, usually colorless, and sneezing. No itching. Summers: always been well until this summer, when nasal symptoms persisted throughout the summer. Patient is an allergic individual, in that ingestion of quinin is followed by urticaria. Mother and two maternal cousins also have idiosyncrasy to quinin, as has the patient's oldest child. Four paternal uncles have bronchial

asthma. She has always had asthma, in addition to her nasal symptoms, at or immediately following Thanksgiving, Christmas and New Year's and during the month of March.

Since the development of symptoms followed deliberate exposure to feathers, it is probable that the reason for the symptoms at these times is due to her dressing the fowl which is eaten at these festivals. The symptoms during March can be accounted for by the necessity of cleaning the chicken houses at that time. Also this is the first year that they have kept ducks, which must be plucked every six weeks, thus accounting for the symptoms occurring during the summer time for the first time this year.

November 19, 1929. Occasional mild symptoms. Food diary discloses onions or chocolate as the probable cause. Has had no incapacitating bronchospasm or nasal symptoms since the experimental observation noted above.

December 9, 1929. Nasal symptoms following exposure to wool (sewing on wool coat). Clinically better since last note, which is coincidental with complete wheat avoidance.

January 11, 1930. Ate wheat (light bread) December 27, 1929; no worse.

February 28, 1930. No further symptoms. Patient cannot be induced to return for experimental repetition of sinus filling and exposure to goose feathers. (C. H. Eyermann, M. D.)

Case 13. Sudden Allergic Reaction

No. 2237. Female, aged 13, schoolgirl. This patient had frequently recurring colds, which persist to this day in spite of all manner of preventive treatment. The attacks occur at any time of year without warning and without much systemic disturbance. When seen at their height, the nasal membrane is everywhere engorged and there is a generous copious purulent discharge. The tonsils have been removed.

Fig 135 Case 13. Postero-anterior view, initial film The membrane is normal in thickness throughout.

The patient is undoubtedly allergic. The secretions, the nature of the mucosa and the type of onset all point to allergy; skin tests with fifty-eight of the common antigens, foods and inhalants have all been negative.

Comment: The interest in this case lies in the sudden thickening of the antral mucosa in the interval between the first instillation of radiopaque oil and the seventy-two hour film. It resembles the foregoing case in its roentgenological findings but differs from it clinically in that severe infections are often present and have recurred for a number of years. After an antrum irrigation through the ostium during an attack, the

Fig. 136. Case 13 The foregoing seventy-two hours later. Membrane thickened.

solution returned clear, in spite of a large amount of pus having been removed from the middle meatus. This may be explained by the practical obliteration of the antral cavity, as shown in the roentgenogram. (Fig. 136.) Here the rapid swelling of the mucosa has probably forced the sinus contents into the nose and the solution returned clear because scarcely any cavity remains within the ostium to contain pus.

Case 14. Allergy—Asthma

No. 3547. Male, aged 42, executive. This patient had had "nasal trouble" since childhood,—chiefly obstruction and rhinorrhea. During his teens he was sometimes treated three

times a day [!] by a laryngologist in St. Louis. While at Yale he had no trouble nor had he any during a trip around the world. For five years, while traveling for his firm in Peoria, Omaha and Milwaukee, he was entirely free from symptoms. On each return to St. Louis they recurred. During the war he was in South Carolina, New York City and Virginia and had no trouble there. On returning to St. Louis, in 1922, he experienced an acute attack of nasal obstruction and asthma which continued for two years, except during visits to Virginia. On two occasions it was thought necessary to drain his antrum several times a day for several weeks, at the end of which time a window was made into it. Allergists had found him skin-sensitive to lima beans and rabbit fur, but his own experiences did not substantiate these findings. Whenever his nose does not drain freely, he develops asthma. In his factory there is a room in which the temperature and humidity can be regulated and the air filtered. He has had an extension made which connects this room with his office and here he is quite comfortable.

The patient was referred to the author for sinus investigation. At that time the nasal mucosa was fairly normal in color. The septum was straight and though its membrane was somewhat irregularly thickened it was not obstructive. There was a permanent window in the right antrum under the inferior turbinate. The middle turbinates were normal in size and the meatuses were free. There was a slight pallor of the turbinates posteriorly and some irregular edema. The plica septi was somewhat thickened on the left side. There was a mild general congestion of the larynx and trachea. Every effort was made to bring about a filling by displacement without success.

Comment: This is undoubtedly a case of allergy, although skin tests are essentially negative. The constant association of

Fig. 137. Case 14. Complete failure to enter with the exception of mere fleck in the right antrum, typical of allergy. Even this small fleck accurately demonstrates the thickness of the membrane on the floor of the antrum, because the film is made with the horizontal beam.

exacerbations of symptoms with pus from the nose points toward a sensitivity to certain bacteria, although the freedom from symptoms when the patient sojourns anywhere except in the Mississippi Valley strongly indicates some plant sensitivity. Tests have utterly failed to determine the allergen. The case is included here with its radiogram (Fig. 137) to demonstrate *the practically complete failure to fill the sinuses* of *allergic* individuals, even though the nasal chambers may be fairly free and give little or no indication of the difficulty. The faint trace of oil on the floor of the left antrum indicates that the failure to fill was not due to a lapse in the technic.

Case 15. Retinal Hemorrhages

No. 2170. Male, aged 62, was referred by an ophthalmologist for examination of sinuses following sudden bilateral retinal hemorrhages. The patient had been throughout his life unusually healthy and active, the only significant circumstance being an attack similar to the present one, which occurred six years previously, leaving the usual scars. The vision had been fair in the interval, and even during the current attack the patient was able to see his way about, but could not read beyond the headlines. Vision in right eye was 3/200 eccentrically. Vision in left eye, 15/20. There were multiple hemorrhages in both eyes and some pigmented areas, the result of the previous attack. The blood pressure was 105/70; Wassermann and Kahn reactions were negative.

Nasal examination revealed an essentially negative nose except for a general thinning of the membrane, apparently senile atrophy, which was not pronounced but resulted merely in an increased roominess of the nasal chambers. There was no indication of localized or generalized infection. The pharyngeal membrane was also slightly atrophic. The tonsils were small and not particularly fibrous. There was no congestion of either the tonsil proper or the anterior pillars. X-ray examination with radiopaques by displacement showed the sinuses essentially negative. There was no indication of membranous thickening anywhere. On the right side there was a pronounced pneumatization of the pterygoid process of the sphenoid bone. (Fig. 138.) Owing to the anxiety of the patient, as well as our own, second films were made after twenty-four hours, instead of the usual seventy-two hours. These showed extensive drainage. A third (forty-eight hour) film showed practically complete emptying. (Fig. 139.) In view of the rapid

Fig. 138. Case 15. Posterior-anterior view, normal filling. Pneumatized pterygoid on the right showing clearly the ridge housing the pterygoid canal through which the vidian nerve passes.

Fig. 139 Case 15. Forty-eight hour film. The cells are practically empty, demonstrating increased rapidity of drainage.

and complete spontaneous drainage it was decided that no sinus operation be done. At the suggestion of a consultant, his tonsils were removed. Pathologist's report: Simple atrophy. At the present writing three years have elapsed without further trouble. There has been a slight improvement in vision and no recurrence of hemorrhages.

Comment: The first films suggested that the pneumatized pterygoid might give rise to some impediment of drainage, which subsequent films showed not to be the case. Prompt drainage contraindicated operation.

Case 16. Choroiditis

No. 2981. Female, aged 29, a saleswoman, was referred by an ophthalmologist for sinus examination. There were a choroiditis and a choked disc on the left side, with loss of vision. Vision in the right eye was 20/19. The onset had been sudden. Three days before the first examination the patient awoke to find the vision in the left eye practically nil, in the center of the field. Marginal vision shortly disappeared. The right eyeground was normal; the left disc was "swollen and hazy, especially above. There was a fluffy exudate with a solid white stellate figure at the macula."

This condition had persisted for seventy-two hours when the first nasal examination was made. The nasal mucosa was then congested and the nose was filled with inspissated pus and mucus. The turbinates were in close contact with the septum. Some adenoid tissue remained, and, after shrinking, streaks of pus were seen emanating from all the posterior cells.

The urine remained negative throughout. Forty-eight hours after the first irrigation this note appears in the history: "Disc edges can now be seen as shadowy outline. Almost all the

large vessels can be followed as they dip over the disc edge. The exudate is becoming either less in amount or is thinning out." The scotoma was much smaller but had not quite disappeared at the end of the week. After the acute nasal condition had subsided, radiopaque studies of the sinuses were made. Average general filling occurred. The seventy-two hour film showed retention in all the posterior cells, a preponderance of oil remaining in the right sphenoid. A bilateral spheno-ethmoid operation was done and the vision returned gradually to 20/30 uncorrected. Since that time, two years ago, there have been minor exacerbations of the nasal inflammation, always accompanied by some reduction in vision. Five months after the operation there occurred a severe acute rhinitis with extreme obstruction. There was a recurrence of the choroiditis; vision in the affected eye fell to 20/60.

Control of the choroiditis in this case apparently depends upon adequate drainage of the posterior cells, as it departed promptly after the operation and recurs with exacerbations of the posterior sinusitis.

This case is presented as an example of impaired drainage of the posterior cells, indicated by the prolonged retention of radiopaques.

Case 17. Choroiditis

No. 3144. Male, aged 29, expressman, referred by an ophthalmologist with a diagnosis of choroiditis and the following history: "Left eye has had poor vision for past five years; 'spots' before left eye past ten years; these 'spots' are coming in the right eye. O. D., vision 6/5, normal eyeground, no cloudiness of media. O. S., 6/40, deposits on Descemet's membrane, increased aqueous flare; massive membranous opacities of vitreous; eyeground can hardly be seen through

Fig. 140. Case 17. Vertical view. Poor general filling. The right sphenoid shows a mere fleck; the right posterior ethmoid slightly more. The left sphenoid is fairly well filled. All these cells show the moderate, irregular filling defect characteristic of true hyperplasia.

haze; large active choroidal lesion 2 disc diameters above disc."

The nasal membrane was red and the nose considerably congested throughout. The septum was deviated somewhat to the left below and to the right above, with moderate obstruction but equal distribution of respiration between the two sides. The tonsils had been cleanly removed, but the pharyngeal lymph nodes were subacutely inflamed, the membranes of the nasopharynx were pale and hyperplastic, and the posterior tips of the middle and inferior turbinates on both sides presented hyperplasias of the "mulberry" type. X-ray examination with radiopaques introduced by displacement showed fairly com-

plete general filling, but seventy-two hour films revealed poor drainage of the posterior cells, which was particularly true of the left sphenoid. The membrane in this cell was thickened to two or three millimeters. The thickening was regular and evenly distributed and closely followed the contour of the bony wall—in other words, a true hyperplasia. (Fig. 140.)

A bilateral sphenoidal-ethmoidal operation was performed. The sinuses contained no pus but the lining membrane was thick, dull and gray. The vision, which had been O. S. 6/40 at the time of operation, returned in six weeks to O. S. 6/12.24.

Case 18. Optic Neuritis

No. 2277. Male, aged 45, was referred by an ophthalmologist for failing vision and frontal headache with a diagnosis of bilateral optic neuritis. Three years before the first examination the sight had begun to fail, and since then had become steadily worse. The trouble began with color defects, and there was now a total central scotoma. The frontal headaches had been fairly constant. The patient's general health had been good, and beyond a mild attack of influenza, six years previously, there was no history of severe infection. Blood Wassermann was negative; spinal fluid clear, colorless, cell count, one; Noguchi globulin test, colloidal gold reaction and Wassermann test all were negative. The urine contained a faint trace of albumin and a moderate number of red blood cells and leucocytes.

Nasal examination showed a general chronic thickening of the mucosa. There was a scant purulent secretion above and below the middle turbinate on the left side, more copious in the olfactory fissure. The posterior nasal membranes were subacutely inflamed and there was a thick mucoid secretion on the faces of both sphenoids, which were irregularly thickened; obviously hyperplastic. The tonsils were small and fibrosed

Fig. 141 Case 18. Lateral view. Sphenoid and posterior ethmoid cells in a case of optic neuritis failed to fill. *In order to verify this in a region which is normally dense and misleading, the film shown in the following figure was made.*

but apparently inactive. X-ray examination by displacement with radiopaques revealed a moderate filling of the anterior ethmoid and maxillary sinuses. The posterior ethmoid cells and the sphenoid were impervious to the fluid. (Fig. 141.) The floor of the sphenoid cavity was fairly thick, and a supplementary film with the patient lying supine was made

Fig. 142. Case 18. Lateral view made in the supine position to verify the fact that the posterior ethmoids and sphenoids did not fill

to eliminate the possibility of having overlooked oil in the sphenoid. (Fig. 142.) Bilateral exenteration of the sphenoids and posterior ethmoids was done at once. The lining membrane was not much thickened but was spongy to the touch and lacked lustre. The vision, which had been so poor that the patient was unable to count fingers on November 18th, the day of the operation, returned as follows:

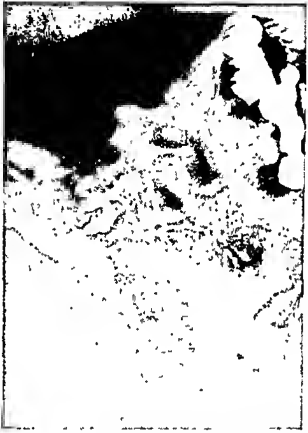
November 25th	O. D. 6/150	O. S. 10/150
November 28th	O. D. 10/96	O. S. 20/96
December 6th	O. D. 20/120	O. S. 20/48
January 9th	O. D. 20/48	O. S. 20/30
February 9th	O. D. 20/38	O. S. 20/24

On December 13th there was still some purulent secretion coming from the openings of both sphenoids which gradually subsided. This was three years ago. At present the vision is still O. D. 20/38, O. S. 20/24.

Comment: The complete failure of the posterior ethmoid and sphenoid cells to fill, in contrast to the normal filling of the maxillary and anterior ethmoid group in the presence of widespread purulent secretion, pointed to the posterior cells as the seat of the disease. The thin walls of the sphenoid also suggested the possibility of direct extension of the infection to the optic nerve. I am aware that the investigations of White[226] and others indicate the infrequency of direct extension from the sinuses as causative of optic neuritis. It also happens that vision in such cases fluctuates and may improve without surgical intervention. I believe, however, that in the light of the nasal findings, both direct and by X-ray, and the progress of the patient following operation, that the sphenoids and posterior ethmoids were the direct causative factor in this case. The failure to fill here pointed to the offending cells.

Case 19. Contracted Visual Fields

No. 2936. Female, aged 8, complained to the ophthalmologist of decreasing vision for the past year. The vision was 15/50 in each eye and both fields were markedly contracted. The fundi were cloudy, gray and blurred. The patient was referred for nasal examination.



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The nasal membrane was congested, presenting some chronic inflammatory changes. The septum was deviated somewhat to the left with moderate obstruction. The tonsils, which were irregularly scarred and ragged, were later removed, but this was done after vision was completely restored and did not enter into the treatment. There was a moderate purulent secretion both above and below the middle turbinates on both sides. The sinuses were irrigated every second day with .5 per cent ephedrin solution by displacement. After the fourth irrigation the vision was 15/30, and after the tenth had returned to normal, where it has remained.

Case 20. Retrobulbar Neuritis

No. 9941. Female, aged 29, housewife. Complained first of dulness of color perception during pregnancy ten months previous to her first examination. Since that time she had had pains in her right arm and some "stiffness" in the right arm and hand.

Two weeks previous to being seen the sight in the right eye suddenly became reduced to a point at which she could distinguish but not recognize persons across the room.

Vision in the left eye remained normal.

The ophthalmologist's diagnosis was optic neuritis and suspected retrobular neuritis.

The patient's general health had always been excellent and the family history was negative. The incapacity of the right arm and hand suggested early multiple sclerosis but there were no other signs.

The nasal mucosa appeared to be normal except for a (perhaps fancied) engorgement of the faces of both sphenoids. The nasopharynx was not inflamed; the posterior margins of the septum and the posterior tips of the turbinal bodies were

not thickened. The tonsils had been cleanly removed, and although there were some prominent superficial lymph nodules on the pharyngeal wall, these were not inflamed.

The X-ray films with lipiodol showed satisfactory complete filling. There were no signs of disturbance in the bones or membranes. Supplementary films (in this case 48 hour instead of the usual 72) showed satisfactory drainage throughout. Dental films showed "periapical infection about the roots of the lower left first molar."

Comment: Much uncertainty exists as to the etiology of retrobulbar neuritis and certainly in such cases the rhinologist bears some responsibility for the outcome until he can be certain that the sinuses are free from infection.

The sphenoidal cavities are difficult to examine and evaluate, especially without a contrast medium, since the surrounding bones are not only relatively heavy but their contours are such that they may readily be mistaken for filling defects. In the lateral views the walls of the cavity are so dense near the floor that they obscure a pool of lipiodol lying there. If this can be missed then surely a diseased membrane which has a lesser density will not be seen.

For examining irregularities of the sphenoid floor the 55° position is usually the most useful; for the back, the submentovertical view. For the region of the ostium, the location most likely to be affected, there is unfortunately no very effective angle. Thickening in this region is usually accompanied by impeded drainage which becomes apparent only in the second series.

Fig. 143 Case 20. First films showing satisfactory general filling. Note especially the ethmoids and sphenoids in question.

Fig. 144. 48-hour film shows normal drainage for that period. Note practically complete emptying of ethmoids and sphenoids

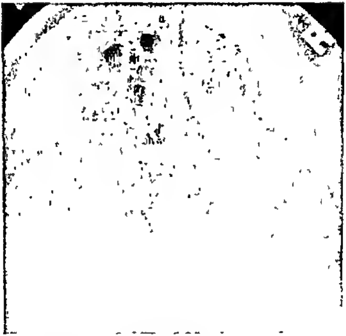

Fig. 145. Case 21.—No. 9191.—Retinitis of four months' duration. Film made May 3, 1944 shows large right sphenoid failed to fill.

Fig. 146. Case 21. Film made May 31, 1944 after treatment (and considerable improvement in the eye) shows large multilocular right sphenoid. Adequate filling.

Fig. 147 Case 22.—No. 9435.—Complete filling in an allergic patient between attacks.

Fig. 148. Seventy-two hour film of the preceding shows retention in the sphenoid with pronounced edema of the membrane, probably due to sensitivity to the oil. It is characteristic of allergic reactions of the sinuses that only one may be affected, as in this case.

Fig 149 Radiograph, lateral view, showing average filling Normal mucosa.

Fig. 150. Radiograph, lateral view, showing average filling. Chronic purulent pansinusitis.

CHAPTER XXI

A REVIEW OF THE LITERATURE OF THE DISPLACEMENT METHOD

Twenty-one years have elapsed since the principle of displacement was first suggested. In the interval, it has been widely accepted, and much that is of interest has been written about it in this country and abroad.

The time seems ripe for an evaluation of the method, based to some extent upon the author's experience, but resting chiefly upon that of others, as expressed in published articles, and in a large number of inquiries and personal comments. Not infrequently these have revealed minor errors in technique or interpretation which have resulted in something less than the successful therapy or diagnosis which might have been attained, wherefore this chapter is appended particularly for those in whose hands displacement has proven impractical as well as for students desiring to perfect their technique.

Some variations in the positions and solutions, and some new instruments have been suggested, but basically the technique remains unchanged. Certain formerly suggested procedures, such for instance, as the prone position for the filling of the frontal sinus, and the use of stained oils for determining emptying time, have been abandoned as impractical.

In regard to general diagnostic considerations one has the feeling that many rhinologists are unwilling to give the time and effort required for proficiency in the interpretation ol radiographs. Certain it is that the properly made film presents considerably more information than is usually gleaned from it

in the course of a routine examination, which is a pity. Wolf[229] makes an observation which should be engrossed and hung on many a wall, when he says, "If we would give our patients nearly as much attention before operation as we do after, our results would undoubtedly be much better."

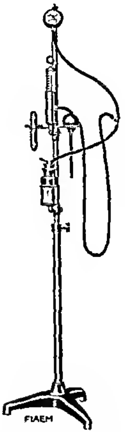

Fig. 151. Monti's apparatus.

TECHNIQUE. LeMée has devised a special metal tip which is in general use in Europe. (Fig. 24.) It has an exceptionally wide control opening and an extra tap for connection with an aneroid gauge to indicate the amount of negative pressure. It has the advantage of being readily disassembled for cleaning, but lacks the glass chamber for observing the secretions removed. The use of the gauge is an excellent safeguard for beginners, though not a necessity in careful hands. For the sake of portability in the clinic, Monti has built a special stand for his equipment. (Fig. 151.) He has also a small metallic suction chamber which attaches to any standard syringe (Fig. 152) and seems very practical. Davis[30] has devised suction apparatus and a folding treatment table for use where space is limited, or even by the patient at home. Thomas[203] employs a mercury manometer which he considers an essential part of his equipment.

An all-glass tip which has given satisfactory results to Kreutz of the Henry Ford Hospital, Detroit, is illustrated in Fig. 153.

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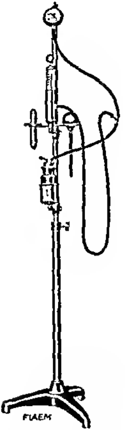

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An all-glass tip which has given satisfactory results to Kreutz of the Henry Ford Hospital, Detroit, is illustrated in Fig. 153.

I mention it only to caution the student against keeping the patient in the extended supine position longer than a minute or two, as severe and sometimes protracted headaches may result.

LeMée,[111] who has a large experience in the teaching of the method, lists the following as the principal errors in technique which he encounters:

1) the use of the wrong radiopaque, resulting in irritation and headache,

2) the use of a cannula not adapted to the nose,

3) failure of the patient to close the pharynx,

4) excessive or insufficient vacuum, the first causing pain or hemorrhage, the second insufficient filling.

5) some malposition of the head.

Richier,[177] finding much variation in the filling of the ethmoids, attempted to establish some standard routine for the best filling. At the Hôpital Necker he performed his experiments upon thirty subjects with apparently normal noses. Checking the viscosity and concentration of the fluids, the degrees of negative pressure, the nasal tip, the position of the head and the number of alternations of pressure, he reached the following conclusions:

1) The "ascending" type of lipiodol enters the sinuses better than the "descending" type. A ten per cent concentration is the minimum for the required contrast.

2) The constant suction pump is decidedly more effective than the rubber bulb.

3) Eighteen centimeters (mercury) is the maximum negative pressure to be used. The rapidity with which the peak-pressure is reached is more important than the total pressure.

4) The best position is a slight exaggeration of the Proetz position.

5) Four cc. is sufficient for one nostril. An amount exceeding this will not increase the filling.

6) Eight alternations of pressure are better than fewer, or even more.

7) Release of suction must be prompt and a long interval between pressure alternations is recommended.

8) The chief sources of obstruction are deviated septa and hyperplastic turbinates.

9) Most sinuses blocked by hypertrophied membranes can be satisfactorily filled after shrinking with cocain and ephedrine, but in such cases the emptying time observations will be unreliable.

SOLUTIONS. On the subject of radiopaques, little is to be added that is new. Some of them have lost favor either because of an unsuitable viscosity or a tendency to become rancid. A few of the original solutions are now standard, and there is not much choice between them. The chief considerations regarding them are that they should be inert and stable, and of a known viscosity; that is, the operator should have knowledge of the average emptying time of the fluid employed.

The author now routinely uses a one-to-three dilution of iodized oil, as recommended by Fraser,[55] and believes that in certain cases an even greater dilution would be preferable. This overcomes *the objection of Hurd*[31] *and others*[1, 28] *who have re*garded the use of radiopaques as disadvantageous because of the possibility of their flowing around a mass and obscuring it. These authors recommend stereoscopic views instead, but we feel that if one is to take two views, a postero-anterior and a lateral view will often give information which the stereoscopic one will not.

Various authors have used colloidal silver salts as radiopaques and found them serviceable.[230] They are less dense than the oils and if retained, may become quite irritating.

LeMée,[109, 115] believes that the elimination of iodized oil may take place through the lymphatics as well as through the sinus ostium by the aid of the cilia. He carefully cleansed the nasal chambers after displacement and retained the patient in the supine position until this was done to guard against swallowing and intestinal absorption. He makes the statement that iodine thus absorbed may be recovered in larger quantities and for a longer time from the urine than from a similar amount ingested. I have been unable so far to find this confirmed by other investigators.

Causse and Bouchet, in discussing this paper, say that they find a similar elimination following the injection of the inferior turbinate with lipiodol for ozena. I do not consider this comparable, as the selective action of the mucosa, which is the important consideration, is lacking in the latter case.

Fenton[46] has observed two persons in whom symptoms of hyperthyroidism seemed to be exaggerated following the use of iodine-containing oils.

Houser[90] used displacement chiefly for posterior ethmoid and spehnoid studies and had the experience that on several occasions when the patient was allowed to assume the erect position, the oil escaped before the films were made. This is a puzzling situation and one is inclined to wonder whether filling actually occurred in the first place or not, or whether possibly too much filling was expected. This thought is injected only because our own experience, even with widely opened sphenoid and maxillary sinuses, is that a certain amount of oil clung to the walls and was distinctly visible.

Houser found that campiodol, diluted with equal parts of olive oil, gave him the best results. The viscosity of this preparation is less than that of a similar lipiodol dilution and is therefore more easily introduced into the sinuses.

It may be well to remind clinicians that variations in the viscosity of the oil will result in concomitant variations in the emptying time and that diagnostic deductions must be based upon the standard emptying time for a given solution.

Williams[106] fears that the "injection of lipiodol into the sphenoid sinus is injurious and one to regard as dangerous and cause for concern," adding that lipiodol is to be used "more in the surgical cases, for when we can show a picture, it is never difficult to get a patient to consent to an operation." With their efficacy in breaking down sales resistance, I have no experience, but if these oils are dangerous there is no intimation of it in the innumerable published records of sinus injections.

For treatment purposes, many solutions have been suggested and used. These fall into three classes: astringents, antiseptics and antigens. Most of these will be discussed under the heading of treatment in connection with their results. One or two, however, should be mentioned here.

Fitzhugh[48] has published his observations of the use of neosynephrin hydrochloride by displacement in the treatment of chronic sinusitis. After reporting a series of fifteen cases in detail, he concludes that a .125 per cent solution of neosynephrin hydrochloride does not protract vaso-constriction longer than does a .25 per cent solution of ephedrine hydrochloride, although in certain cases it is less toxic. He finds that "although neosynephrin hydrochloride is somewhat more expensive than the solution of ephedrine hydrochloride, it can be used in those cases in which the patient is sensitive to ephedrine and

should be substituted intermittently for the ephedrine solution in cases in which long periods of treatment are required"—presumably in order to avoid developing a tolerance for either drug.

Layman,[105] in 1929, irrigated antrums by displacement after packing the posterior half of the nose with absorbent cotton slightly impregnated with mineral oil. This procedure was applied especially to acute cases. He found it of advantage to instill at first one to two cc. of the solution of ephedrine and cocain. Warm saline solution was employed for the irrigation.

Shambaugh[183] found a .25 per cent solution of ephedrine sulphate in physiological solution of sodium chloride quite as effective as the .5 per cent solution which I had recommended and less likely to produce an ephedrine reaction. Following his example, I now use this strength routinely, and prefer it. The total dose of ephedrine which the patient receives in the case of the .5 per cent solution is roughly .6 grain; with the .25 per cent solution it is .3 grain.

TREATMENT. Many solutions are being employed by various rhinologists, but in the main it may be said that the simple constrictors in dilute, usually isotonic solutions, have served best.

Arslanian and Valette,[7] working in Portmann's clinic, use iodized poppyseed oil 40 per cent, or strong or mild silver protein. They report fifteen cases with good results in all. They allowed the negative pressure to mount to 240 mm. of mercury. Treatments were given at four and five day intervals and were found by them to be especially effective in children.

Bouchet and Mazarakis[17] use isotonic solutions of various compositions, colloidal silver, protargol and lipiodol with olive

oil. On occasion they have employed weak anesthetic solutions. Among these, one per cent cocain solution was found to be ineffective. Butylene was badly tolerated. Their experience is that the first day following a filling, the head is heavy, on the second day secretions appear in the pharynx, followed by an interval of relief beginning on the third day.

C. K. Beck reports that 5 per cent solution of neosilvol was ineffective, and one-half of one per cent solution of mercurochrome was followed by severe local irritation, nausea and headache lasting about twenty-four hours.

Baum[10] cautions that displacement cannot be depended upon to fill sinuses in the presence of allergy. This is in accord with the author's observation that "while the complete failure to fill may hardly be advanced as pathognomonic of allergy, it is so striking as to be highly suggestive. Small amounts of fluid may be made to enter, however, by preliminary shrinking." This procedure has on occasion been of great service in relieving acute attacks of seasonal allergy when local applications have failed.

Frazee,[61] observing the emptying time in a series of twenty cases, states that "check-up plates made seventy-two hours after the introduction of the iodized oil show some fluid remaining. This is what Proetz terms delayed emptying."

I wish to caution the reader that actually my observations showed (see p. 161) that, using iodized oil of a specified viscosity, ninety-six hours were required for the sinuses to empty themselves. The seventy-two hour period was adopted as routine not only for convenience and expedition but also because some small amount of fluid did remain to indicate the position of the cells under observation. This author has also the impression that I advise surgical treatment for sinuses which do not admit fluids. In a measure this is true, but it

should be understood that by fluids I mean all fluids and not only radiopaques. Many sinuses which will not admit radiopaques can be made to accept ephedrine after shrinking, and it is often in these cases that the greatest good may be expected.

As Frazee has applied the method, he has not found it to add any important findings not previously shown in his routine roentgen examinations, but his experiences with treatment have been somewhat better. Sixty-three per cent of sixty-eight patients with headache were improved. In seven cases the headache was increased.

Ridpath[178] found the method effective in a case of frontal sinusitis following influenza.

Shuster and Shuster[157] point out that displacement is to be used, in acute sinus infections, only as the acute symptoms subside.

Davis[39] reports that the method acts more quickly in children than in adults; that in order to be of benefit it must be used several times a week and sometimes over a long period of time.

Iglauer[97] finds it possible to introduce fluids into otherwise inaccessible ethmoid cells and to free them of their retained secretions. He regards the use of opaque oils in this region as advantageous in diagnosis.

Winfred Post has had satisfactory results in ophthalmologic lesions secondary to acute nonsuppurative posterior sinusitis and pharyngitis. He employed the treatment daily for a week, although the pains became negligible much earlier. In a case of acute iritis, the exudate into the anterior chamber began to recede after the second treatment, and disappeared on the eighth day.

Theobald,[202] discussing a paper of Vail, describes the case of a woman, aged 30, who was rapidly becoming blind in one

eye through a retrobulbar neuritis. On the affected side, the sphenoid refused the oil. He expressed the opinion that "whether there was a thickened mucous membrane or not was not of importance. This sinus was completely blocked. She was operated upon and counted fingers on the third day and read a newspaper inside of a week."

Wagner[215] feels that the important factor in displacement is the dilution of the pus, which facilitates its removal, although at times he has difficulty in making the fluid enter the sinus. The solution of his choice is one of physiological sodium chloride. The same author,[216] as late as 1936, states that his radiographs of the ethmoids are unsatisfactory and that it is impossible to irrigate these cells. Others, however, have succeeded in filling them fairly routinely, and many prints of radiographs showing them well filled may be found in the literature. (See for example Figs. 63 to 72.)

Curiously, Liggett and Caldas have independently found displacement the most successful means of evacuating the sinuses of larvae. Liggett[117] saw a 15-year-old girl who complained of a copious nasal discharge. There was also a hawking of pus, always preceded by a tickling sensation in the roof of the mouth. A vigorous attempt to clear the throat brought up a living insect about one cm. long, dark brown and many-legged. This happened about once every two to four weeks. Sometimes two, rarely three, insects appeared. On a previous occasion, three or four months before, she observed six or seven worms entirely different from these parasites. They were quite small and had no legs. Roentgenograms of the sinuses were negative. It seemed certain that the parasites were lodged in the right maxillary sinus. However, a radical operation was done on both sides. The left antrum appeared normal except for a slight thickening of the mucosa. The right

was filled with a mass of polyps and necrotic tissue. Fluid pus was present, and although the cavity was curetted in its entirety and a careful search was made for larvae, none were found. No ova or parasites were found in the tissues removed.

The headache was now more apparent in the occipital region. Accordingly, under local anesthetic, the sphenoid sinuses were punctured and the openings bitten out with punch forceps. Irrigation of these sinuses, however, failed to produce any larvae, although the washings from the right side were cloudy and contained mucopus, epithelial cells and cholesterol crystals. Within ten minutes after this procedure the patient blew three living insects from her nose. Subsequent irrigations produced two or three more parasites. To facilitate the washing, the right middle turbinate was excised. Finally the patient was subjected to a displacement filling, using a commonly employed oil prepared after a formula of Coakley. The paper was written nine months after this treatment and no further larvae had been seen. The insect was identified by an entomologist of the Smithsonian Institute as the larva of the black carpet beetle (*attagenus piceus* Oliv.). This larva takes two years to reach the adult stage.

Caldas[23] reports three cases of nasal larvae treated by means of displacement. In the tropical regions, according to this author, myiasis of the sinuses is not rare among the rural population. The flies are usually the *musca domestica*, *sarcophage ruralis* and *wohlfartia magnifica*. When the larvae reach the interior of the sinuses, the condition is curable only with great difficulty. The usual treatment consists in washing with some lotion and then extracting the larvae with forceps. This treatment is insufficient, because many of the invaders are left behind in the nasal cavities.

This author has experimented with various larvicides in vitro, including various coal tar derivatives, oxycyanate of mercury, corrosive sublimate, 10 per cent carbolic acid, iodoform in liquid vaseline and iodoform in ether. He found that these did not kill the larvae but often increased their movements. The effect of these preparations in the nose has been merely to drive the larvae out of the sinuses into the nasal chambers, whence they could be removed with forceps. In order to reach all of the sinuses simultaneously, Caldas introduced an "iodoformed paraffin oil 5 per cent" by the displacement method. In the three cases reported, all the larvae were quickly washed into the nose and removed. In each case the patient returned several times during the first twenty-four hours to have more insects taken away. In each case also the process was complete within that time and no further larvae appeared.

Of late much interest has been directed toward the effects of various biological preparations upon the sinus mucosa. Amano[3] writes of ten patients with chronic paranasal sinusitis and one with ozena treated by displacement every two or three days for several months, using autogenous vaccines and antivirus. These treatments were supplemented by occasional packs with the same materials. Seven showed improvement, four did not. The results were not sufficiently striking to permit of drawing conclusions, but the author suggests that this may be a step toward the improvement of present-day methods of treating these troublesome diseases.

Kracaw,[100] in 1934, employed displacement for filling the posterior sinuses with antigens prepared according to the Krueger methods. In a series of 45 cases, 95 per cent showed satisfactory improvement, and 66 per cent a very pronounced improvement or cure. Continuing his studies in 1936,[101] "appli-

cation to the sinuses every fourth day is effected by the Proetz displacement technique. This is adequate for the treatment of the ethmoidal and sphenoidal sinuses, and if properly carried out results in instillation of some of the antigen in the antra. * * * Local reaction manifesting itself in slight nasal obstruction, and in some cases by mild headache, follows the first few instillations. As treatment is carried out the drainage increases and becomes purulent—a favorable indication, since the antigen apparently acts by stimulating phagocytosis. Finally the drainage becomes mucopurulent and gradually diminishes in quantity."

Hosmer,[89] discussing Kracaw's work, reports his own successful results and mentions the necessity for thorough shrinking before administration. He finds the "lysate superior to antiseptics such as mercurials or phenol in oil."

Laskiewicz[102] treated ethmoiditis with a complicating maxillary sinusitis in an infant as follows: He put a polyvalant antivirus with adrenalin into the nose. On the second day, the temperature remaining at 38 degrees, he introduced 2 ccm. of antivirus by displacement. On the third day the temperature dropped to 37.5 degrees and the mucosa improved in appearance. A second displacement was given the following day, after which the infant left the clinic practically recovered. He then conducted a parallel series, comparing the effects of disinfectants with those of antivirus. In three cases the infection disappeared in three to five days, which were the most satisfactory results of the various treatments, and were accomplished with the use of antivirus by displacement. He feels that "this method covers a vast domain of application in the treatment of sinus infections."

Gundrum and Semenov,[78, 79] in two comprehensive articles, describe their observations on 150 cases treated by displace-

ment with ephedrine .5 per cent. Fifteen to twenty instillations were given in each case. Fifty-two per cent of the cases were definitely improved (that is, relieved of headache, postnasal drainage and obstruction). Sixteen refractory cases which failed to show improvement were treated with a stock bacterial antigen filtrate prepared from staphylococcus, streptococcus and bacillus coli according to the method of Bezredka. Eleven of the sixteen cases improved after the addition of bacterial antigen to the ephedrine solution.

One hundred and thirty-five additional cases were treated, using stock bacterial antigen with ephedrine from the beginning. In this series 64 per cent improved.

Eleven cases were treated with undenatured autogenous antigen according to the method of Kracaw. In this series the results were no better, only six of eleven having definitely improved. They add the important observation that bacterial filtrate and bacteriophage are quite irritating to the sinuses and not infrequently bring about severe reactions. For this reason they begin with dilute solutions. They conclude that "beneficial results obtained with dilute ephedrine in physiological sodium chloride solution, as advocated by Proetz, can no longer be open to doubt. The shrinkage action is smooth and protracted and the total quantity of ephedrine which is given in the routine treatment seldom creates undesirable symptoms; as a matter of fact, few systemic effects have so far been observed * * * the best results are obtained in the subacute catarrhal type of sinusitis." They feel that the addition of a dilute solution of bacterial antigen can be made without discomfort to the patient. If progress justifies the continuation of the antigen, the concentration may be increased until a 50 per cent solution is obtained. By this method definite improvement was noted in more than 64 per cent of their cases.

With any solution the percentage of improved cases varies so greatly from month to month, and from epidemic to epidemic, that these figures seem to me to fall well within the average fluctuation. Frazee, for instance, cited above, reported 63 per cent favorable results without using antigens, and my own results are comparable.

Monti[137] has found the method satisfactory, using a polyvalant antivirus. Parkinson[146] has used bacteriophage, but I do not know his results.

Hirst feels that it is practically impossible to infect a normal sinus in the course of treatment, but on two occasions suspected that there was a subacute exacerbation of a chronic ethmoiditis and chronic maxillary sinusitis. The maxillary sinusitis had been quiet for a long time. Following this experience, he has routinely douched noses with physiological sodium chloride solution before giving a displacement treatment.

Mignon[136] has attempted displacement in the ear in cases of otitis media. This report is mentioned for the sake of completeness and without any wish to advocate the treatment. I know of no one else who has attempted it, and should not regard it as being free from danger.

Radiography. Through the writings of such men as Ernst,[55] Baum and Israel[20] in this country, Graham-Hodgson[71, 72, 73] in England, Sourice,[196] Gunsett et al.,[80] and LeMée[111] in France, and Vock[214] in Germany, the use of the horizontal beam with the patient in the upright position has, within a very few years, become standard practice. This eliminates many errors of judgment in the interpretation of filling defects, more especially those resulting from evenly thickened membranes.

A common source of supposed failure has been the desire for complete filling and metallic shadow density. Such shad-

ows produce a dramatic contrast as viewed from across the room, but they obliterate much that is essential, and, I am sure, are the cause of much adverse criticism. The remedy is, of course, a fluid of low opacity, and a partial filling. One or two cc. or less will suffice to indicate the emptying time of a cell, and it will do something else, seldom referred to by its critics, it will flow into the most unexpected pockets and ramifications, demonstrating extensions of sinuses into regions quite unsuspected in the "straight" film. I know that it will be said that a competent radiologist can outline these without the oil. Experience makes me doubt that there are many who can do so.

Even with the help of the oil, it is often necessary to resort to two views for a proper interpretation. Beeler, in discussing a paper of Bundy Allen,[1] stresses the importance of taking two views routinely. When one considers the difficulty of identifying even a familiar person by his shadow, unless it happens to be in frank profile, the limitations of the one-view routine become evident. Carmack's[215] chief difficulty was that the very cell which interested him most was often the one which did not fill!

Fraser[60] considers that the observation of delayed emptying time has merit, and suggests keeping some sort of protocol of the patient's activities and postures during the seventy-two hour observation period. It is his experience also that the nonsuppurative type of infection tends toward pan-sinus distribution, to demonstrate which, with radiopaques, displacement is necessary.

Glaser, Futch and Snure,[61] in 1929, studied the literature for opinions on the reliability of simple X-ray studies, and found many reports of negative X-ray findings in sinuses which at operation were found to contain pus and many more which

were found to be not diseased in spite of increased density to the rays.

Goodyear[64] stresses the importance of maintaining the same angulation in the making of the 72-hour exposure as the one employed for the initial one, in order to avoid errors in interpretation.

LeMée once showed me a film in which flecks of radioopaque oil could be seen deep in the cervical tissues following a displacement. In his large experience, it was the only one, and it is difficult to explain how it may have come there. Pfahler[151] reported a similar distribution following antrum puncture. While he attributed this to absorption of the oil by the sinus mucosa and a final collection by the lymphatics, a study of his published radiographs leads one to regard an accidental submucosal injection of the oil as the more likely explanation. He also finds no other case, either in the literature or in his own files. It would seem that if true lymphatic drainage of iodized oils could occur it would have been observed more frequently among the hundreds of thousands of patients injected in the past thirteen years.

Bedford Russell has made the observation that on some occasions a sinus with a thickened mucosa has emptied itself of its oil in shorter time than its fellow, which showed no such thickening, and raises the question whether or not ciliary activity may at times be greater in an inflamed sinus than in a normal one. I have no answer for him as to the modus operandi of the phenomenon, but regard his discovery, that thickened membrane and delayed emptying do not necessarily go hand in hand, as extremely important. I submit that this contribution could never have been made without the use of a fluid radiopaque.

INTERPRETATION AND DIAGNOSIS. Competent diagnosis from films made with radiopaques is the most difficult phase of the displacement method, and requires both judgment and experience. However, it seems to me that the results are well worth the study. Only in the dissecting room is one confronted so forcibly with the endless variation in sinus distribution. In the flat film there is always the tendency to select from the shadows those which conform to the text-book description, often with considerable error.

A number of articles have appeared which are of practical value. In gathering some of these for discussion, great care has been exercised to exclude those early ones which dealt with films exposed with the vertical beam. In the nature of things, these shadows were quite incapable of accurate interpretation, and gave rise to much confusion. Since the general correction of this error, there can be seen a growing uniformity of diagnostic judgment among those whose interest has survived the change.

Coates[30] considers displacement of great help in ethmoid diagnosis. He writes: "The displacement method of introduction [of radiopaque substances] * * * gives us much diagnostic information if properly carried out. * * * The method is so simple that anyone can avail himself of it, and all of the sinuses, including the frontals and maxillaries, can be sufficiently filled at one sitting for a very complete diagnosis, albeit *many radiologists do not feel the need of this method for arriving* at a roentgenologic diagnosis. Formerly it was of common occurrence to receive reports of extensive ethmoid disease in the absence of diagnostic clinical signs. This is less common now, due to improvements in technique, but the overlying cells in this area usually make for confusion and difficult interpretation. * * *

"Where it is difficult or impossible to place a pack with the turbinate in situ, the Proetz displacement irrigation is often most effective. It is a very simple office procedure that patients, even young children, take to readily if they once see the method demonstrated upon another individual, and they often become enthusiastic about the results obtained. Various solutions may be used, the most common being normal saline solution, one-half of one per cent ephedrine sulphate in normal saline, or, as Ridpath prefers, poppyseed oil. The method is reasonably safe, although on two occasions I have seen some middle ear inflammation develop, which may or may not have been a coincidence. Because of this I rarely use the method in acute ethmoid infections. I have a few patients who have developed the art of giving themselves their own Proetz irrigations at home."

On the subject of possible ear infection, Davis[34] says, "I have heard of a few ear infections following this treatment in acute cases but none in chronic cases." So far as I know, no middle ear infection has ever followed any treatment in my own hands, but I have been careful to avoid irrigating noses in the acute stages and have frequently referred to the possible dangers of doing so.

Special problems sometimes require deviations from the routine for their solution.

Some months ago a medical student was brought to me in whom an osteoma of the frontal sinus had been discovered in the course of a maxillary sinus investigation. The osteoma occupied the upper mesial corner of the sinus, and it was important to determine whether or not the internal plate was involved. The routine positions failed to show this, as the oil lay on the floor of the sinus and did not reach the tumor.

Fig. 156. Radiopaque introduced by displacement, and radiograph made with patient still supine. Position of the oil demonstrates that the osteoma is attached to the internal plate.—(Courtesy Edward Mallinckrodt Institute of Radiology.)

identical plane of the bony cavity reveals a filling defect, which is, after all, the purpose of the whole investigation.

The sudden thickening of ostensibly normal membranes as the result of allergy has been verified by Dean,[57] and extreme variation in the extent and distribution of such thickenings has been pointed out by Beeler, Smith and Collins.[12]. Their quotation from Jones to the effect that oil remaining more than forty-eight hours is pathological, leads one to caution the student that this, while possible, must apply to an oil which is much less viscous than most of those in common use. The emptying time is in inverse ratio to the viscosity of the oil, provided that the ciliary activity is the same in both cases. It is the common experience that such oils as lipiodol diluted with an equal amount of olive oil, or brominol (light) require nearly ninety-six hours to leave the normal sinus completely. Certain aqueous solutions disappear in twelve hours.

In this connection, the observations of Whitney and Doub[227] are noteworthy. These authors, examining a series of twenty cases at the end of forty-eight hours find some oil remaining in sixteen of them. Only twelve of these sixteen showed pathological changes. Among the four which emptied themselves in forty-eight hours, no filling defect was found. Unfortunately these observations were not continued beyond forty-eight hours, so that no report appears regarding the fate of those twelve pathological and four normal sinuses which retained oil. Our own experience is that a normal sinus empties itself of about one-half the contained oil in each twenty-four hours. The variations to which this rule is subject are not sufficient to invalidate it.

The reproductions of the radiographs appearing on the following pages are appended because they demonstrate graphically two conditions in which the seventy-two-hour observation is particularly useful.

Fig. 157, a submento-vertical view, shows an average filling of the various sinuses. There is nothing here to indicate any abnormality. Taken alone it might well be passed as a normal nose. The one noteworthy feature is the relatively scant filling of the right sphenoidal sinus (left side of illustration) as compared to its fellows on the left and right of it. One suspects some difficulty about the ostium.

Fig. 158 shows the left sphenoid which filled readily enough, retaining oil to a pronounced degree, while the rest empty. Whatever the cause there is obviously something wrong with the ability of the sinus to empty itself promptly.

Fig. 159 is particularly noteworthy for the extensive pneumatization of the sphenoids including the posterior clinoid processes. Either the patient was sensitive to the oil, or underwent an allergic attack from some other cause.

Fig. 160 shows the same sphenoid 72 hours later at the height of the attack. The thickened membrane is plainly seen at the top and bottom of the sinus. Also the swollen membrane in the body of the sinus has forced the oil to the top and is in the act of extruding it through the ostium.

Fig. 159. Lateral view. The ethmoids show the flecking characteristic of allergic rhinitis. The large frontals have admitted a few drops of oil. The maxillary sinuses show average filling. The sphenoid sinuses are extensively pneumatized, including the rather large posterior clinoid processes. The sphenoids are half full of oil.

Fig. 160. Seventy-two-hour film of the preceding. A localized allergic reaction has occurred in the sphenoid. The other cells have emptied themselves. The swollen membrane in the sphenoid which can be plainly seen front and back above and below has prevented the normal escape of the oil, but has forced it to the top where it is being slowly extruded through the partially obliterated ostium.

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